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Anthropometric Prediction Equations for Estimating Muscle Mass of Elderly Women

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Abstract

Muscle Mass (MM) has an important role in health and physical performance. There are many MM prediction equations, but none is formulated in Indonesia. This study aimed to develop Anthropometric Equations (AE) prediction for MM. A cross sectional study was used to formulate AE prediction through multiple regression analysis. The significance of observed differences between predicted and actual MM was tested by t test while level of agreement was assessed by Bland Altman plot. A significant correlation was found between MM and height, body mass index, calf/arm/waist circumferences, and waist hip ratio ($p<0.05$). Regression analaysis indicated that age, height, and Mid Arm Circumference (MAC) contributed significantly to MM. The resulting equation was MM (kg) = -10.22+(-.097x age)+(0.16xheight)+(0.30xMAC). There was no significant difference between actual and predicted MM results, and both had significant correlation. These results suggest that age, AP related to MM and AE provide valid prediction of MM for healthy elderly women in Jakarta.

Introduction

Muscle mass represents about 40% of total body weight. It is an important body component and plays a significant role in health status such as insulin resistance and basal metabolism which affect the risk for type 2 diabetes, obesity, dyslipidemia, and metabolic syndrome (Ishii *et al.*, 2014 , Burini and Maestá, 2012, Baek *et al.*, 2014). Muscle mass of elderly people is very important to their activities of daily living, therefore decline in muscle mass due to aging is one of the contributors for sarcopenia and results in a decrease in capacity for independent living and an increase in fall risk and death among the elderly (Chen *et al.* 2013, Schaap *et al.*, 2013). Health problems and physical performance issues due to decreased muscle mass are major public health concerns in elderly populations especially women, thereby leading to important socioeconomic consequences (Baek *et al.*, 2014, Burini and Maestá, 2012, Ishii *et al.*, 2014 , Chen *et al.* 2013).

Muscle mass measurements were performed by estimating fat volume and lean body mass through various measurements including Magnetic Resonance Imaging (MRI), Computed Tomography Scan (CT scan), Dual Energy X-ray Absorption (DXA) and Bioelectrical Impedance Analysis (BIA). Among the various muscle mass gauges, there is non-invasive, portable, and cheap tool such as Bioelectrical Impedance Analysis. However,

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the use of Bioelectrical Impedance Analysis techniques is limited in research and clinical practice since it is often impractical for the elderly due to hydration state, inadequate protein ingestion and physical condition (Chen *et al.*, 2015, Wang *et al.*, 2016). Therefore, it is necessary to measure muscle mass more easily such as anthropometric measurements. Previous studies have shown that there is a correlation between anthropometric parameters and muscle mass measurements. Anthropometric parameters such as body height, body weight, body mass index (BMI), waist circumference (WC), waist hip ratio (WHR), calf circumference (CC), mid arm circumference (MAC) are simple, inexpensive and noninvasive methods to measure body composition (Marcus *et al.*, 2012, Quinonez-Olivas *et al.*, 2016, Kuriyan and Kurpad, 2004, Santana *et al.*, 2015). Anthropometry has been used as a practical alternative in estimating muscle mass in men, women, young and elderly individuals through application of the prediction equations method (Kuriyan and Kurpad, 2004, Pereira *et al.* 2013, Santana *et al.*, 2015, Brito *et al.*, 2016, Quinonez-Olivas *et al.*, 2016).

There are few reports of total body muscle mass mass in Indonesia and no anthropometric-predicted equation for muscle mass have been developed and are applicable to elderly women in Jakarta. In a developing country like Indonesia, medical practitioners need to use simple anthropometric measurements to predict the average muscle mass of elderly to detect sarcopenia earlier in primary care and to improve therapeutic strategies in order to prevent the muscle mass reduction, which is the most common characteristic of sarcopenia. Therefore, this study aimed to analyze the relationship between simple anthropometric parameters and muscle mass in elderly women in Jakarta and to compare the results of muscle mass between actual measurements using BIA as the reference method and predictive equations based on simple anthropometrics for elderly women in Jakarta.

Method

We used observational analytic study. This cross-sectional study examined 96 elderly women subjects which were 60 years age or more, who have lived in nursing home for minimal 2 years, were healthy and independent in their basic daily living activities. We excluded any subjects with history of routinely consuming drugs that affect muscle mass (such as ACE inhibitor, steroid or growth hormone, etc.) in the past year, chronic or acute severe comorbidity, and subjects with extremity edema or ascites. Volunteers with disabilities, inability to perform the measurement of BIA due diseases or refuse to make any anthropometric measure were excluded. The subjects mainly came from lower socio-economic status, living in four Tresna Werdha Budi Mulia Social Institution nursing homes, at DKI Jakarta, Indonesia in October 2016.

All measurements were taken by the same trained investigator to ensure reliability. Subjects' body weight and height were measured while they were dressed in light clothing and without footwear and expressed to the nearest 0.1 kg and 0.5 cm using automatic scales and wall-mounted stadiometer connected to the scales. Body mass index was measured based on body height and weight as follows: body weight in kilograms divided by body height in meters squared. All circumferences, waist circumference, waist hip ratio, calf circumference and mid arm circumference were measured in centimeters (cm) using a flexible non-elastic measuring tape with standardized equipment and procedures and were obtained in duplicate (Kuriyan & Kurpad, 2004; Brito *et al.*, 2016; Santana *et al.*, 2015; Quinonez-Olivas *et al.*, 2016). Waist circumference was measured at umbilical level with subject standing. Calf circumference was measured from the largest circumference of right leg calf when subject is sitting and reflecting the right foot (Quinonez-Olivas *et al.*, 2016). The mid arm circumference was measured at non dominant arm in standing erect posture. The subjects' elbow was flexed to 90^0 and circumference is measured at the mid-point between acromion tip and olecranon process (Kuriyan & Kurpad, 2004; Pereira *et al.* 2013, Brito *et al.*, 2016).

Muscle mass measurement was estimated by bioelectric impedance analysis (BIA) using the Bioscan 916 body composition analyzer with operating frequency of 50 kHz at 0.7mA (Maltron, UK). This muscle mass measurement procedure lasted 5 to 10 minutes for each study subject and was carried out by the same technician who calibrated the device according to the manufacturer's recommendations. For the assessment, subjects were instructed to take off any metallic prosthesis or objects and lay on the examination bed in a supine position with arms slightly abducted from the trunk and legs slightly separated on a non-conducting surface. Surface electrodes were placed on the right side of the body on the dorsal surface of the hands and feet at two areas: firstly, proximal to the metacarpal-phalangeal and metatarsal-phalangeal joints, respectively, and secondly, medially between the distal prominences of the radius and ulna and between the medial and lateral malleoli of ankles. The muscle mass index (MMI) was calculated as [muscle mass (kg) ÷ height (m)^2] (Chen *et al.*, 2015, Han *et al.*, 2016).

All measurement variables and calculated values were expressed as mean ± standar deviation. Data normality was confirmed using ladder test. Pearson and Spearman correlation coefficient analyses were used to calculate the relationship between anthropometric parameters and muscle mass. The values of p = 0.05 or less were considered statistically significant. The value of correlation were reported as Cohen's based on pooled values of 0.2, 0.4 and 0.6 as references for small, medium, and large correlations, respectively (Cohen, 1988). Linear regression models were performed to measure the values of anthropometric parameters variables (age, body height, body weight, body mass index, waist circumference, waist hip circumference, calf circumference and mid arm circumference) and to predict muscle mass. Based on this analysis, a mathematical equation was proposed to predict muscle mass. We also determined the differences between muscle mass and actual muscle mass index measured obtained by Bioelectrical Impedance Analysis with the predicted values obtained from the proposed regression model using the paired t-test. Bland-Altman plots was used to check the agreement between actual and predicted muscle mass and to describe the average difference (bias) and the respective limits of agreement (mean difference ± 2 up to the difference of: 95% limits of agreement, which gives an indication of the precision of the method) *GraphPad Prism* version 7 (Liu *et al.*, 2014). The alpha level for testing significance was set at $p < 0.05$. All statistical analyses were performed using STATA statistic package, version 12.0.

All participants were informed about the study procedures before participated and informed consent was taken beforehand. The study received ethical approval from the Medical and Health Research Ethics Committee (MHREC) Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada (Ref: KE/FK/599/EC/2016).

Results and Discussion

The muscle mass, age and anthropometric parameter characteristics such as body height, body weight, body mass index, waist/calf/mid arm circumference and waist hip ratio for the 96 elderly women subjects are presented as mean and standard deviation in Table 1. In this study, the mean of muscle mass was 14,27 kg and muscle mass index was 6,69kg/m^2 .

To calculate the relationship between muscle mass and anthropometric parameters, this study used Pearson and Spearman correlation coefficient analyses (Table 2). There were significant negative correlations among age, waist hip ratio and muscle mass of subjects.

This study also showed that there were significant positive correlations among anthropometric parameters: body height, body mass index, waist circumference, body weight, calf circumference, mid arm circumference and muscle mass actual measured by BIA (p<0.05) with body weight having the strongest correlation with muscle mass (r=0.59).

In Table 3, the result of stepwise multiple regression analysis showed that age, body height and mid arm circumference (MAC) were selected as significant contributors to predict muscle mass (r^2=0.70, F=68.16). In this study, there was an increase of 0.2 kg or 0.3 kg of muscle mass per 1 cm of body height or mid arm circumference, which highlights its importance for muscle mass prediction.

The Bland Altman plot presents the agreement between the anthropometric-predicted equation muscle mass or muscle mass index and actual measured muscle

Table 1. Subject Characteristics of the Study Population

Variables	n	Values (mean±SD)	
Age (years)	96	70.64	± 9.07
Height (m)	93	1.46	± 0.06
Weight(kg)	93	47.14	± 9.65
Body mass index (kg/m^2)	91	22.00	± 4.71
Waist circumference (cm)	94	80.82	± 11.66
Waist hip ratio (cm)	93	0.89	± .08
Calf circumference (cm)	95	31.64	± 1.53
Mid arm circumference (cm)	95	26.00	± 4.32
Muscle mass (kg)	94	14.27	± 2.26
Muscle mass index (kg/m^2)	94	6.69	± 0.91

Table 2. Correlation Between Age, and Anthropometric Parameters and Muscle Mass

Skeletal Muscle mass (kg)	R	p
Age (year)	-0.53*	<0.05
Height (m)	0.45*	<0.05
Body mass index (kg/m^2)	0.41*	<0.05
Waist circumference (cm)	0.34*	<0.05
Waist hip ratio (cm)	-0.01*	<0.05
Weight (kg)	0.59**	<0.05
Calf circumference (cm)	0.43**	<0.05
Mid arm circumference (cm)	0.54**	<0.05

*Pearson correlation**Spearman correlation

Table 3. Prediction Model of Muscle Mass in Elderly Women.

Variable	Model of prediction	R^2
MM (kg) = -10.22 + (-.097*age) + (0.16 *height) + (0.30*MAC)		0.70

MM = muscle mass; MAC = mid arm circumference; R^2 = variation

mass or muscle mass index (Figure 1). The concordance between the anthropometric-predicted equation muscle mass and actual measured by Bioelectrical Impedance Analysis (BIA) were: *bias*= 0.29 and SD=4.30 and limits of agreement of 95% for (-8.14; 8.71).

The concordance between the anthropometric-predicted equation muscle mass index and actual measured muscle mass index were *bias*= 0.06 and SD= 1.97 and limits of agreement of 95% for -3.79; 3.91). There were significant differences in observed data between muscle mass index (F=15.63; $p<0.05$), but no difference was found between the anthropometric-predicted equation and actual measured muscle mass (F=1.11; $p>0.05$).

There were significant correlations between the anthropometric-predicted and actual

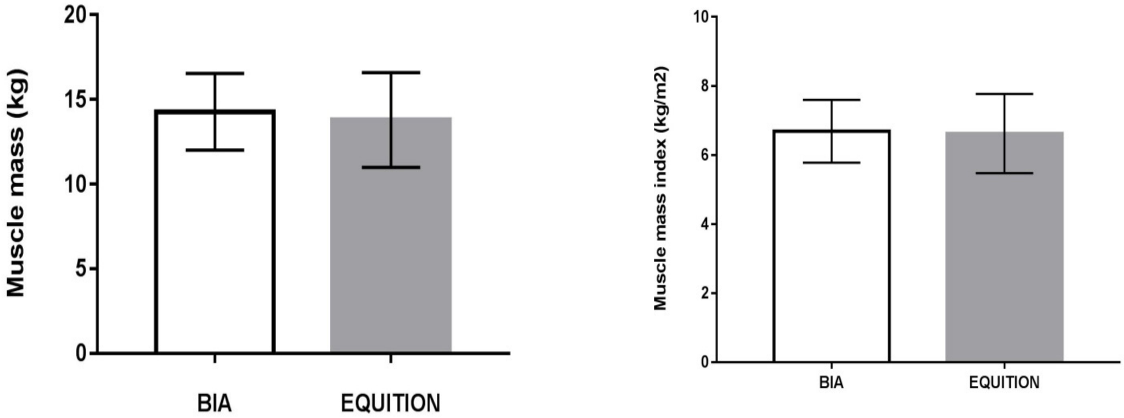

Figure 1. Muscle Mass (MM) (Panel A) and Muscle Mass Index (MMI) Value (Panel B) Obtained by BIA and Estimated by Equation in Elderly

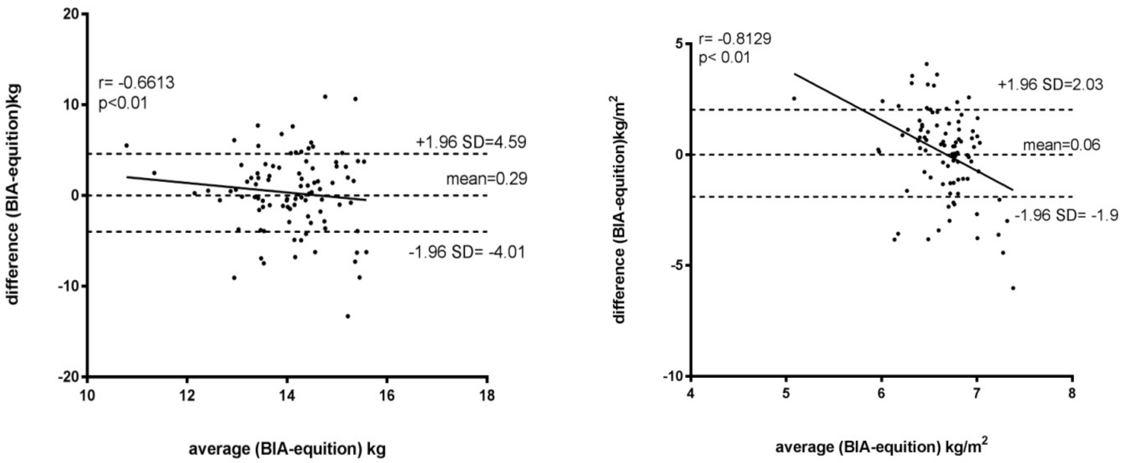

Figure 2. Correlation between the Values of Actual and Predicted Muscle Mass (kg) (Panel A) and Muscle Mass Index (Panel B)

muscle mass in the Bland-Altman analysis. The dotted lines represent the 95% confidence interval. The continuous line represents the average standard error (Figure 2).

To our knowledge, this study is the first to illustrate the average elderly muscle mass in Jakarta with different tool, which is Bioscan 916 body composition analyzer (Maltron, UK), and to examine the relationship between anthropometric parameters and muscle mass among elderly women in Jakarta using Bland Altmand analysis. The findings of this study were: a) age was significantly correlated with muscle mass; b) anthropometric parameters were significantly correlated with muscle mass with body weight being the main predictor of muscle mass; and a novel finding c) the proposed equation based on age, height, mid arm circumference had a significant positive correlation with muscle mass.

Characteristics of subjects in this study were mostly educated for 6 years or less, Javanese race and had average age of 70.64 years (Yuliastuti and Anggoro, 2017). This is no different from other studies where most subjects' education level was low (Yuliastuti and Anggoro, 2017). The mean height, weight and body mass index of the study subjects were lower than outside studies (Santana *et al.*, 2015; Quinonez-Olivas *et al.*, 2016).

Muscle mass is the largest organ in the mature human body. Muscle mass involved in many biological processes like metabolic homeostasis, physical strength and daily living activities (Baek *et al.*, 2014; Burini & Maestá, 2012; Chen *et al.* 2013; Schaap *et al.*, 2013). Therefore, knowing the condition of muscle mass is very important in maintaining health and activity. Bioelectrical impedance analysis is a reproducible method to measure body composition, for predicting and evaluating skeletal muscle mass with 54,2% sensitivity and 98,3% specificity. Bioelectrical impedance analysis is one of the standard tools recommended to measure body composition because it is safe, reliable, simple, non-invasive and valid. In addition, bioelectrical impedance analysis equipment is portable and inexpensive. Study shows that muscle mass measurements using BIA are positively correlated with muscle mass prediction using MRI and which shows excellent accuracy in older adults (Wang *et al.*, 2016) or the best alternatives to MRI to estimated muscle mass (Palle *et al.*, 2016). The estimation of total body muscle mass is also important for evaluating the influence of muscle mass to health (Chen *et al.*, 2015; Wang *et al.*, 2016).

The mean of elderly women muscle mass in this study was 14,27 kg. The mean value of this muscle mass was still within the lower range of other studies that indicates the mean muscle mass in elderly women range from 13,8 to 19,3 kg (Legrand *et al.*, 2013; Auyeung *et al.* 2014; Santana *et al.*, 2015; Han *et al.*, 2016; Quinonez-Olivas *et al.*, 2016). This value is roughly close to the average of muscle mass in elderly people in China (Wang *et al.*, 2016). Based on some studies, it appears that the mean muscle mass in this study was below the cut off for women muscle mass associated with weakness, 15,02 kg (Cawthon *et al.*, 2014; McLean *et al.*, 2014). The average low muscle mass in this study was supported with a lower calf circumference score in this study of 31.63 cm, compared to other studies (Santana *et al.*, 2015 , Quinonez-Olivas *et al.*, 2016). This is related to studies which suggest that muscle mass is strongly correlated with calf circumference values (Kawakami *et al.*, 2015). Low muscle mass in low boundaries might be due to racial differences, educational level, and lifestyle (nutrition and activity) which will influence nutritional status characteristic such as body height, body mass index, as well as due to differences in muscle mass measurement instruments used (Marcus *et al.*, 2012; Legrand *et al.*, 201; Auyeung *et al.* 2014; Han *et al.*, 2016; Yu *et al.*, 2015). Studies showed that racial differences influence muscle mass. It appears that muscle mass is higher among subjects from certain races (Silva *et al.*, 2010). Other explanations that contribute to low muscle mass of this study are the different levels of activity and socioeconomic level and cultural environment. Studies show a difference in activity between elderly people living in nursing homes compared to others (coast or urban) (Yuliastuti & Anggoro, 2017). The study also shows that the quality of life of elderly people in Surabaya is strongly influenced by socio-economic factors and family roles (Sincihu *et al.*, 2018). The studies show that the better assessment of association muscle mass with physical performance is expressed to muscle mass index based on body height. Therefore, this study assessed the average of muscle mass index based on body high from this study subjects was 6. The value of this muscle mass index is higher than elderly subjects in China (Wang *et al.*, 2016) but lower than other research (Santana *et al.*, 2015; Yu *et al.*, 2015). Although the value of muscle mass index in this study was lower (Santana *et al.*, 2015; Yu *et al.*, 2015) and stated in the categorization of subjects with muscle weakness, but the muscle mass index value this study was above the cut-off value of low muscle used in the Yu study (5.35 kg/m2) (Yu *et al.*, 2015). This result is supported by a study which states that the mean of muscle mass index of this study (6.69kg / m2) is not considered as sarcopenia diagnoses by Asian Working Group for Sarcopenia (AWGS) since the cut-off rate of muscle mass for sarcopenia diagnosis is above 5.7 kg / m (Chen *et al.*, 2014).

The value of good muscle mass index and not classified in sarcopenia was supported with the mean value of mid arm circumference better than other studies (Brito *et al.*, 2016; Santana *et al.*, 2015).

Our study found that age variable indices are more valuable to assess muscle mass that age is negatively correlated with muscle mass. Our results are consistent with the findings of a previous study that showed increased age was associated with muscle mass loss (Auyeung *et al.* 2014; Ryall *et al.*, 2008; Joseph *et al.*, 2012; Ishii *et al.*, 2014). The results of this study are consistent with previous studies which suggest that increase in age is correlated with decreased muscle mass. It is associated with aging process that causes decreased function of various organs or increased oxidative stress affecting various mechanisms of protein catabolism and anabolic pathway in muscle tissue. Various factors that affect the decrease in muscle mass due to increased age are (1) Increased mitochondrial dysfunction causing energy production disturbances (ATP); (2) Increased oxidative stress that causes cell destruction, especially lipids and proteins that interfere with cell homeostasis; (3) Due to increased incidence of various diseases affecting the production of inflammatory markers and other processes affecting the muscle atrophy process; (4) Decrease in the number of satellite cells resulting in decreased regeneration of muscle tissue; (5) Increased shifting of type II muscle fiber to type there is decreasing number and size of fiber muscle type II (Ryall *et al.*, 2008; Joseph *et al.*, 2012; Legrand *et al.*, 2013; Natasa *et al.*, 2015).

Based on correlation analysis in the present study, we identified that there are correlation between muscle mass and anthropometric parameters. Body weight, body height and mid arm circumference were more strongly correlated variables with muscle mass, while body mass index, calf circumference, waist circumference, waist hip ratio were also suitable for estimating muscle mass. This finding is reasonable since a number of studies show that protein as the main component of muscle mass is associated with anthropometric parameters such as body height, body weight, calf circumference and mid arm circumference (Brito *et al.*, 2016; Merchant, 2005, Marcus *et al.*, 2012, Santana *et al.*, 2015; Quinonez-Olivas *et al.*, 2016). Studies that support the finding that increased waist hip ratio is correlated with decreased muscle mass are as follows (1) Increased waist hip ratio is associated with increased fat accumulation inducing pro-inflammatory conditions, insulin resistance, fat infiltration and cell metabolic disorders. This leads to decreased protein synthesis, and increased intramuscular fat tissue proteolysis; (2) Increased waist hip ratio is associated with chronic disease or decreased aerobic endurance or impaired activity thus increasing the risk of protein catabolism and exacerbating decreased activity that increase the risk of decreased / lost muscle mass (Marcus *et al.*, 2012; Legrand *et al.*, 2013). Therefore, maintenance of anthropometric status in elderly women appears to be an important strategy to keep the muscle mass.

Furthermore, population-specific anthropometric prediction equations for estimating muscle mass have been reported previously (Kuriyan & Kurpad, 2004; Yu *et al.*, 2015; Santana *et al.*, 2015). However, no prediction equations have been developed in Jakarta for Indonesian population. This study provided equations for the prediction of muscle mass from simple anthropometric parameters, which found that muscle mass was adequately estimated by age, body height and mid arm circumference, using Bioelectrical Impedance Analysis as the reference method. Importantly, these anthropometric measurements are simple and easy to perform in practical situations by clinicians and health professionals, optimizing the planning and implementation of interventions in order to diagnose and prevent sarcopenia. Our findings show no significant difference was observed and also significantly high correlations between actual values of measured muscle mass by BIA and predicted muscle mass results. These findings suggest that our anthropometric prediction equations have a valid and high accuracy for estimating muscle mass. These results are in line with previous studies which also identified the potential of simple measurement like body mass, calf circumference and mid arm circumference to estimate the muscle mass (Pereira *et al.* 2013; Yu *et al.*, 2015; Kuriyan & Kurpad, 2004; Santana *et al.*, 2015). From two simple measurements, height and mid arm circumference combined with age, the practitioner can now predict muscle mass measurement, and maintenance of mid arm circumference in elderly women appears to be important strategy to keep the muscle mass. The comparison of our results indicated that derived anthropometric prediction equations were more applicable to Indonesian populations in Jakarta with body height and body mass index where subject characteristics are different than previous studies (Deurenberg *et al.*, 2002; Santana *et al.*, 2015). The estimations of total muscle mass will optimize early identification of sarcopenia and may lead to interventions to reduce the impact of this important women's health issue by helping the planning and implementation of interventions to diagnose sarcopenia early and prevent it.

Our study has certain limitations. The first limitations of this study is its cross sectional study design. The second is the use of elderly women in Jakarta which is a homogenous community and the relatively small sample size of subjects. The third, Muscle mass was estimated using Bioelectrical Impedance Analysis (BIA) and not Magnetic Resonance Imaging (MRI) as a gold standard (Heymsfield et al., 2014). Thus, our study population may not accurately represent the general population of elderly Indonesian women. Further study is needed to examine the reliability of the equation to predict muscle mass in the elderly.

Conclusion

In conclusion, the results of the present study documented a simple anthropometric prediction equation to be a fast and reliable measurement to accurately and adequately predict muscle mass in elderly women such as height and mid arm circumference. The major contribution of this study was to establish anthropometry muscle mass prediction equations applicable for healthy Jakarta elderly women and is relevant to medical practitioners in the evaluation and early prevention of decreased muscle performance among elderly, including maintenance of healthy nutritional status. Further studies need to be done on a larger sample size to confirm the results of this study.

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