Prediction Model of Appendicular Muscle Mass using Mid-thigh Circumference, Calf Circumference, and Mid-upper Arm Circumference in Community-dwelling Elderly in Indonesia

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Abstract

Muscles play an important role in daily activities. Aging causes low muscle mass, which has many negative effects such as weakness, decreased mobility, limitation to do daily activities, etc. However, not all appendicular skeletal muscle mass measurements are easy to use and not expensive. This study aimed to identify a prediction model as an alternative method to measure appendicular muscle mass based on mid-thigh circumference, calf circumference, and mid-upper arm circumference. A cross-sectional study design was used; the study included 99 individuals,aged ≥60 years (37 men and 62 women) in Kadumanggu Village in West Java, Indonesia. The subjects were recruited, then anthropometric parameters were measured using nonelastic ONEMED OD 235 tape; body height was measured using the GEA Staturemeter 2M, weight and appendicular skeletal muscle mass were measured using a Bioimpedance Analysis (BIA) Omron HBF-375 Karada Scan by trained examiners. Multiple regression analysis was performed on SPSS version 16 software to obtain the best prediction model. The prediction model results were: Appendicular Skeletal Muscle Mass (kg) = (64.171 x Height (m)) + (1.710 x Body Mass Index (kg/m^2)) – (0.109 x Mid-Upper Arm Circumference (cm)) + (0.178 x Calf Circumference (cm)) + (0.033 x Mid-Thigh Circumference (cm))– (0.535 x Weight (kg)) – (0.065 x Age (years)) – 98.098 for men ($R^2 = 0.710$; SEE = 1.43 kg; $p<0.05$) and Appendicular Skeletal Muscle Mass (kg) = (8.987 x Height (m)) – (0.170 x Body Mass Index (kg/m^2))– (0.117 x Mid-Upper Arm Circumference (cm)) + (0.121 x Calf Circumference (cm)) – (0.025 x Mid-Thigh (cm)) + (0.160 x Weight (kg)) – (0.059 x Age (years)) – 6.491 for women ($R^2 = 0.700$; SEE = 1.23 kg; $p<0.05$). Difference model based on sex, showed satisfactory result for predicting appendicular skeletal muscle mass in the elderly in Indonesia. However, further research is needed to validate these findings.

Keywords: *Appendicular muscle mass, prediction model, elderly.*

Introduction

In the human body, muscles have many functions, such as transforming chemical energy to mechanical energy (body movements), storing nutrition, and contributing to basal metabolism Skeletal muscle mass (SMM) comprises approximately 40% of total body weight(1). As human gets older, fat mass tends to increase while SMM and skeletal mass decrease(2). Some studies have reported on the negative effects of low muscle mass, such as weakness, decreased mobility, limitations in doing daily activities, difficulty maintaining balance, and increased risk of fracture(2-4). Appendicular skeletal muscle mass (ASM) is the component of muscle mass that comprises approximately 75% of total SMM. ASM measurement is important in a nutritional and physiological study related to aging, muscle wasting, and obesity.

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Anthropometry measurements can be used as a body composition method to obtain information on ASM[5]. On the one hand, Dual-energy X-ray Absorptiometry (DXA) is known to be the gold standard for this measurement[6]. On the other hand, this method cannot be used in community-based clinical settings due to its high cost, limited access, and risk of radiation exposure to users[5]. Therefore, another method is needed to measure ASM that is community-friendly. Some studies have reported that body measurements can be used as a predictor to estimate ASM in the elderly[7–10]. The present study focuses on three body measurements: mid-thigh circumference (MTC), calf circumference (CC), and mid-upper arm circumference (MUAC). MTC is selected because the thigh has the highest percentage of muscle in the human body (25% of total SMM);CC has the second highest percentage of muscle (9.5% of total SMM), and MUAC has the highest muscle mass percentage in the upper extremities (5% of SMM)[11]. These measurements are also relatively easy to conduct, and, to the best of our knowledge, no other research has been conducted to develop a prediction model from these body measurements to estimate ASM in the elderly. Thus, this study aimed to develop apredictión model of ASM using MTC, CC, and MUAC in an elderly population in Indonesia.

Method

This cross-sectional study was conducted using a convenience sample of community-dwelling elderly in Kadumanggu Village, Bogor District, West Java. This study's sample consisted of 99 elderly individuals; most of the participants were women (62.6%). Mean age was 71.68±7.26 years for men and 69.14±7.47 years for women. Mean ASM was 8.13±3.03 kg and mean body mass index (BMI) was 22.33±4.04 kg/m^2.

The inclusion criteria were: individuals aged ≥60 years, those who do not stoop, have never had a part of their body amputated, and are not disabled. The exclusion criterion was anyone who was suffering from bone fracture at the measurement area. After the 99 subjects were recruited the anthropometric parameters (MTC, CC, and MUAC) were measured using nonelastic ONEMED OD 235 tape[12]; body height was measured using the GEA Staturemeter 2M[13], weight and ASM were measured using Bioimpedance Analysis (BIA) Omron HBF-375 Karada Scan[14] by trained examiners. After collecting all the anthropometric data, multiple regression analysis was performed on SPSS version 16 software to identify the best prediction model using single to multiple variables for the sex-specific (Men-Only and Women-Only) and combined sex (Both-Sexes) prediction models.

Weight and ASM were performed with subjects wearing a minimum amount of clothing that was free of metallic objects. ASM data were collected by multiplying the total percentage of upper and lower extremity muscle mass with body weight; height was measured with the subject removing any kind of footwear or headgear. MTC was measured by wrapping nonelastic tape around the skin between the thigh crease and the upmost part of the patella. CC was measured at the widest part of the calf. MUAC was measured on the skin at the middle point of the acromion and olecranon bones.

Eight predictors were used in this study: weight, height, BMI, MTC, CC, MUAC, age, and sex. The researcher used 338 possible combinations from these predictors, differing by sex and by combing both sexes, beginning with one predictor and then all eight predictors to obtain the highest r square (R^2) possible from each category. The paired t-test, Pearson's linear correlation coefficient, and the coefficient of determination (R^2) were used to assess the validity of selected prediction models.

Findings

Data for the general characteristics of the study participants is shown in Table 1, expressed as frequencies or means ± standard deviation (SD), with minimum-maximum given in the brackets. The data showed that ASM and height were significantly higher in the men than the women.

Table 1. General Characteristics of the Sample and Differences based on Sex

	Whole Sample (n=99)	Men (n=37)	Women (n=62)
Age (Years)	70.09±7.46 (59.70-90.50)	71.68±7.26 (60.20-90.50)	69.14±7.47(59.70-86.00)
Weight (kg)	52.28±1.19 (28.70-78.10)	53.37±8.10 (34.30-73.30)	51.62±1.38 (28.70-78.10)
Height (m)	1.52±0.71 (1.31-1.70)	1.50±0.54 (1.42-1.70)	1.50±0.68 (1.31-1.65)
BMI (kg/m^2)	22.33±4.04(11.53-34.25)	21.61±2.81 (14.65-28.91)	22.76±5.09 (11.53-34.25)
ASM (kg)	8.13±3.03 (2.54-16.27)	10.46±2.69 (5.06-16.27)	6.75±2.30 (2.54-14.31)
MTC (cm)	41.20±6.29 (27.30-55.40)	40.42±5.61 (29.22-52.60)	41.66±6.67(27.30-55.40)
CC (cm)	30.96±3.72 (21.10-40.70)	31.27±2.90 (26.60-36.50)	30.77±4.14 (21.10-40.70)
MUAC (cm)	27.30±4.59 (18.50-38.90)	26.26±3.25 (18.50-33.10)	27.91±5.16 (19.70-38.90)

Three prediction models (Men-Only, Women-Only, and Both Sexes prediction models) were found to have the highest R^2 from three categories, and each had a p value <0.001. Table 2 shows the development and cross-validation for the selected ASM prediction model.

Table 2. Development and Cross-validation of the ASM Prediction Model

Sex	Prediction Model Development			Cross-validation		
	Equations	R^2	SEE	Difference Mean (SD)	Paired t-test*	R
Men	= 64.171 x height + 1.710 x BMI – 0.109 x MUAC + 0.178 x CC + 0.033 x MTC – 0.535 x weight – 0.065 x age – 98.098	0.710	1.43	0.02	0.915	0.843
Women	= 8.987 x height – 0.170 x BMI – 0.117 MUAC + 0.121 x CC – 0.025 x MTC + 0.160 x weight – 0.059 x age – 6.491	0.700	1.23	-0.03	0.846	0.837
Both Sexes	= 0.301 x weight – 0.688 x height – 0.065 x age + 0.139 x CC + 0.125 x MUAC – 2.466 x sex – 0.487 x BMI + 9.933	0.777	2.51	-2.01	<0.001	0.882

BMI: Body Mass Index; MUAC: Mid-upper Arm Circumference; CC: Calf Circumference; MTC: Mid-thigh Circumference; Sex: 1 for men and 2 for women, *Paired t-test performed to compare actual ASM with predicted ASM

Satisfactory results were found in the Men-Only and Women-Only model due to its high R^2 (men=0.710, women=0.700) with low Standard Error of Estimate (SEE) (men=1.43 kg, women=1.23kg), while the models for Both-Sexes prediction model had a high R^2 (0.777) and the highest SEE (2.51 kg). Data from the actual ASM measured by BIA were applied to cross-validate these three models. The result of the paired t-test showed that there were no significant differences between the ASM measurements obtained by BIA and the Men-Only prediction model and Women-Only prediction model; however, there was a significant difference between the measured ASM and the Both-Sexes prediction model. The correlation coefficient between the measured and predicted ASM ranged from 0.837 to 0.882.

Discussion

This study aimed to identify the best ASM prediction model for Indonesian elderly using body measurements due to the impractical use of DXA as the gold standard to measure ASM in community-dwelling elderly. This measurement is important for a nutritional and physiological study related to aging, muscle wasting, and obesity(15). Furthermore, many studies have reported that weakness, decreased mobility, limitations for doing daily activities, difficulty maintaining balance, and increased risk of fracture are related to low muscle mass(2-4).

In our study, most of the subjects were women, and many of them were living with their children after their husbands had passed away. This is also because women have a higher life-expectancy than men. The Central Bureau of Statistics declared that Indonesian women's life expectancy is 73.06 years; for men, it is 69.16 years[16]. In our study, ASM was greater in the men than the women, because, in men, testosterone had a positive correlation with muscle mass and muscle strength. Although testosterone decreases with age the testosterone level is still higher in men than in women[17].

The MTC measurements were higher in women than in men; in contrast the ASM was lower. This means that there was another body composition underneath the muscle mass, which is fat. Women have higher levels of estrogen before menopause; this hormone is responsible for fat distribution in the thighs, hips, and arms. This is why our results showed that the women had greater MUAC than the men[18].

The R^2 for men, women, and the Both-Sexes prediction model were 0.710 (SEE = 1.43 kg), 0.700 (SEE = 1.23 kg), and 0.777 (2.51 kg), respectively. The results for the Men-Only prediction model were similar to the findings reported in previous studies; the ASM models from Martin et al.[19] had R^2 = 0.74 with SEE=1.94 kg and the models from Doupe et al.[20] had R^2= 0.77 with SEE=1.94 kg. The results for the Women-Only prediction model were similar to the findings reported in Santana et al.[9] which had R^2 = 0.650 with SEE = 1.83 kg. The result for the Both-Sexes prediction model was not satisfactory due to high SEE, and the difference in the mean was approximately 2 kg, which was underestimated. Based on the positive predictive value using the Asian Working Group on Sarcopenia (AWGSOP) cut-off for healthy muscle mass (7.0 kg/m^2 for men and 5.7 kg/m^2 for women)[21], this ASM prediction model could find 100% positive cases (low muscle mass) for men, 99% for women, and 99% for both sexes. Thus the Men-Only prediction model and Women-Only prediction model performed satisfactory and can be used as a screening tool to identify low muscle mass in the elderly.

Conclusion

In general, based on data from a population of Indonesian elderly, two prediction models were found to be satisfactory for estimating ASM. The result suggests that the developed equations had satisfactory prediction qualities and could be applied to measure ASM in community-dwelling elderly in Indonesia, although a validation study is still needed to determine the validity of this prediction model.

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Ethical Approval: This study was approved by The Research and Community Engagement Ethical Committee Faculty of Public Health Universitas Indonesia (number 20/UN2.F10/ PPM.00.02./2019).

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