Original Article

Relationship between Calf Circumference and Skeletal Muscle Index among Community-Dwelling Thai Elderly

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Background: A strong association between calf circumference (CC) and skeletal muscle index (SMI) has been established worldwide in the elderly, however, these data in the Thai population are lacking.

Objective: To evaluate the relationship between CC and SMI, as well as to identify the important predictors of SMI among the community-dwelling Thai elderly.

Materials and Methods: The present study was an analytic cross-sectional study performed in 110 community-dwelling adults aged 60 years and older who lived in Sriracha, Chonburi, Thailand. Weight, height, and the maximum CC were measured in standing position. Body composition was measured using the bioelectrical impedance analysis (BIA) and the SMI was calculated as the appendicular skeletal muscle mass (ASM) divided by the height squared (kg/m^2). Pearson's correlation was used to indicate the relationship between CC and SMI. Multiple linear regression was developed to predict SMI.

Results: The prevalence of low muscle mass in men and women were 23.5% and 33.3%, respectively. CC had a positive correlation with SMI ($r=0.75$; $p<0.001$). The cut-off values for predicting low muscle mass using CC were 34.0 cm (sensitivity 85.5%, specificity 71.8%, AUC 0.895) in women, and 33.4 cm (sensitivity 75.0%, specificity 92.3%, AUC 0.925) in men. Multiple linear regression analysis revealed age, gender, weight, and CC as the key predictors for SMI with adjusted r^2 of the model equal to 0.80. CC and weight had a direct effect on SMI. On the other hand, age was inversely related to SMI. Women had lower SMI than men.

Conclusion: CC was positively associated with SMI, and it could be used as a screening tool to identify the community-dwelling Thai elderly with low muscle mass in the field settings. Important predictors of SMI were age, gender, weight, and CC.

Keywords: Calf circumference; Skeletal muscle index; Sarcopenia; Low muscle mass; Aging; Appendicular skeletal muscle mass

Received 14 June 2021 | Revised 25 September 2021 | Accepted 27 September 2021

J Med Assoc Thai 2021;104(11):1814-20

Website: http://www.jmatonline.com

Sarcopenia is one of the most common geriatric syndromes, which refers to the constant loss of skeletal muscle mass, strength, and function, resulting in poor capability of daily routine activities and increased risk of falling, disability, and death[(1)]. Among Asian older adults, the reported prevalence of sarcopenia had a great variation, ranging from 5.5% to 25.7%[(2)]. The previous studies affirmed that the differences in the prevalence of sarcopenia depends on ethnicity, population setting, gender, instruments of measurements, methods of determining cutoff values, as well as the diagnostic criteria[(3,4)], hence, it is difficult to compare the prevalence of sarcopenia among the various studies.

The Asian Working Group for Sarcopenia (AWGS) has supported the appendicular skeletal muscle mass (ASM) measurement using the bioelectrical impedance analysis (BIA) in community setting[(5)]. Height-adjusted ASM or skeletal muscle mass index (SMI) cutoffs was used for low muscle mass detection in sarcopenia diagnosis as follows with less than 7.0 kg/m^2 in men and less than 5.7 kg/m^2 in women by BIA[(2)]. Nevertheless, the multifrequency BIA is not available everywhere especially in the rural areas and many limitations in specific individuals had been observed[(6)]. Therefore, a simplified anthropometric tool for the clinical assessment of sarcopenia is required.

Recently, the AWGS 2019 suggested using calf circumference (CC) for screening older adults who

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How to cite this article:

Tannirandorn A, Pangkanon W, Prachansuwan A, Isarashewawat P. Relationship between Calf Circumference and Skeletal Muscle Index among Community-Dwelling Thai Elderly. J Med Assoc Thai 2021;104:1814-20.

doi.org/10.35755/jmedassocthai.2021.11.13031

were at risk for sarcopenia[2]. CC measurement is a simple, fast, and non-invasive method to assess nutritional status[7]. Even though several studies have revealed that CC can be used as a predictor of muscle mass particularly ASM, the correlation between CC and skeletal muscle mass tend to vary by ethnicity[8-12]. Moreover, many factors including age, gender, body mass index (BMI), residence, drug use, smoking status, alcohol consumption, and physical activity level were observed to be associated to the skeletal muscle mass[13-20].

Nonetheless, to the best of the authors knowledge, studies on the CC and SMI among Thai elderly are limited. Thus, the purpose of the present study was to evaluate the relationship between CC and BIA-measured muscle mass among community-dwelling Thai elderly, and to identify other useful predictors for low muscle mass.

Materials and Methods

Study population

The analytic cross-sectional study was conducted in Sriracha, Chonburi, Thailand between July 2017 and February 2019. Participants who lived in Sriracha and had never been diagnosed with sarcopenia were recruited.

Participants with the following conditions were excluded 1) participants with history of hospital admissions in the past three months or taking medications that affected muscle mass over the past year, including sex hormones, growth hormones, thyroid hormones, and steroids, 2) participants with congestive heart failure based on the New York Heart Association stage 3 or higher, uncontrolled chronic obstructive pulmonary disease, chronic kidney disease stage 5, chronic liver disease with Child-Pugh Score class B or C, connective tissue diseases, neurodegenerative diseases, terminal cancer, or tuberculosis, 3) participants with metallic implants, such as orthopedic prosthesis, coronary stents, or having implanted cardiac devices including pacemakers and defibrillators, which are the limitations of BIA[6], 4) participants who underwent intense exercise or consumed alcohol 12 hours before participating in the present study.

Data collection

All measurements were conducted in the morning after fasting for at least four hours. Participants were asked to wear loose-fitting outfits. General information including gender, age, health problems, statin use, smoking status, alcohol consumption, and level of physical activity were obtained. Smoking status was categorized into three groups, non-smoker, ex-smoker, and current smoker[21]. Alcohol consumption was divided into three levels, non-drinking, moderate drinking, and heavy drinking[22]. Physical activity level was classified into three levels of physical activity as low or less than 600 metabolic equivalent of task (MET) minutes per week, moderate or 600 to 1,500 MET minutes per week, and high or 1,500 or more MET minutes per week[23].

Anthropometric measurements were evaluated by well-trained medical assistants. Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. BMI was calculated as the weight divided by the square of the height in meters (kg/m^2). CC was measured while standing with the feet positioned 20 cm apart by using the non-elastic tape without putting any pressure on the skin to obtain the maximum circumference. CC measurement was conducted in duplicate on each leg to acquire the average results for one leg. Then, the average of the maximum circumference of both legs was calculated. The unit of measurement was done in cm with the nearest 0.1 cm.

Body fat mass and skeletal muscle mass were determined for the segmental multi-frequency BIA (InBody 270; InBody Co. Ltd., Seoul, South Korea) in a standing posture. ASM was defined as the sum of all appendicular skeletal muscle mass of legs and arms. Height-adjusted ASM of SMI, according to the AWGS 2014, was then calculated as ASM in kilograms divided by height in meters squared (kg/m^2)[24].

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics, version 24.0 (IBM Corp., Armonk, NY, USA). Descriptive analysis was displayed in terms of number and percentage for categorical variables. Mean and standard deviation (SD) were used for numerical variables. When the data were skewed, median and interquartile range (IQR) were applied. Pearson's correlation was used to analyze the relationship between CC and SMI, considering a strong correlation if $r>0.7$. The receiver operator characteristic (ROC) curves and area under the curve (AUC) were analyzed for CC in both genders to evaluate the finest cut-off values of CC for predicting low muscle mass. Multicollinearity and multiple linear regression analysis with forward stepwise procedure were developed with SMI as a dependent variable and other factors as independent

Table 1. Characteristics and prevalence of low muscle mass of the study population

Characteristics	Total (n=110); n (%)	Women (n=93); n (%)	Men (n=17); n (%)
Age (year); median (Q1, Q3)	69 (64, 75)	69 (64, 75)	72 (64.5, 76.5)
Health problems			
Diabetes	32 (29.1)	27 (29.0)	5 (29.4)
Hypertension	60 (54.5)	49 (52.7)	11 (64.7)
Hyperlipidemia	55 (50)	50 (53.8)	5 (29.4)
Use of statins	49 (44.5)	45 (48.4)	4 (23.5)
Smoking status			
Non-smoker	101 (91.8)	90 (96.8)	11 (64.8)
Ex-smoker	6 (5.5)	3 (3.2)	3 (17.6)
Current smoker	3 (2.7)	0 (0.0)	3 (17.6)
Alcohol consumption			
Non-drinking	92 (83.6)	82 (88.2)	10 (58.8)
Moderate drinking	15 (13.7)	11 (11.8)	4 (23.6)
Heavy drinking	3 (2.7)	0 (0.0)	3 (17.6)
Level of physical activity			
High	10 (9.1)	10 (10.8)	0 (0.0)
Moderate	92 (83.6)	77 (82.8)	15 (88.2)
Low	8 (7.3)	6 (6.4)	2 (11.8)
Weight (kg); mean±SD	58.9±9.2	58.1±8.6)	63.1±11.4
Height (cm); median (Q1, Q3)	153.4 (151.0, 157.0)	152.6 (150.3, 154.8)	161.2 (158.1, 168.8)
BMI (kg/m^2); mean±SD	24.8±3.7	25.0±3.8	23.5±3.0
Fat mass (%); mean±SD	34.8±7.4	36.5±6.4	25.7±5.5
ASM (kg); median (Q1, Q3)	14.4 (12.9, 16.3)	14.1 (12.6, 15.5)	19.2 (17.6, 20.9)
SMI (kg/m^2); median (Q1, Q3)	6.1 (5.6, 6.9)	6.0 (5.5, 6.6)	7.3 (6.9, 7.7)
Average calf circumference (cm); mean±SD	34.3±2.9	34.2±3.0	35.2±2.2
Low muscle mass	35 (31.8)	31 (33.3)	4 (23.5)

BMI=body mass index; ASM=appendicular skeletal muscle mass; SMI=skeletal muscle index; SD=standard deviaiton

variables as a predictive equation with adjusted coefficient of determination (adjusted r^2). A p-value of less than 0.05 was considered statistically significant.

Ethics statement

The present study was conducted in accordance with the 1975 Helsinki Declaration (revised in 1983) and approved by the Ethical Committee of the Queen Savang Vadhana Memorial Hospital (264/2561). The clinical trial was registered at the Thai Clinical Trials Registry with the identification number: TCTR20210528001. All participants were provided written informed consents before participating in the present study.

Results

One hundred ten older Thai adults including 93 women and 17 men, were enrolled into the present study. The median age was 69 years, with women predominance (84.5%). Forty-nine subjects (44.5%) used statins as a lipid lowering medication. Most participants never smoked (91.8%), did not consume any alcohol beverages (83.6%), and had a moderate physical activity (83.6%). Of the anthropometric parameters, the mean (SD) of weight and BMI were 58.9 (9.2) kg and 24.8 (3.7) kg/m², respectively. The median of SMI in men and women were 7.3 kg/m² and 6.0 kg/m², respectively. The average of CC (SD) was 35.2 (2.2) cm in men. In women, the average of CC (SD) was 34.2 (3.0) cm. According to the AWGS 2019, the cut-off values of SMI at 7.0 kg/m² in men and 5.7 kg/m² in women when assessed by the BIA were used[2]. In the present study, the prevalence of low muscle mass was 31.8% with 23.5% in men, 33.3% in women, as shown in Table 1.

Figure 1a shows the ROC curve for female

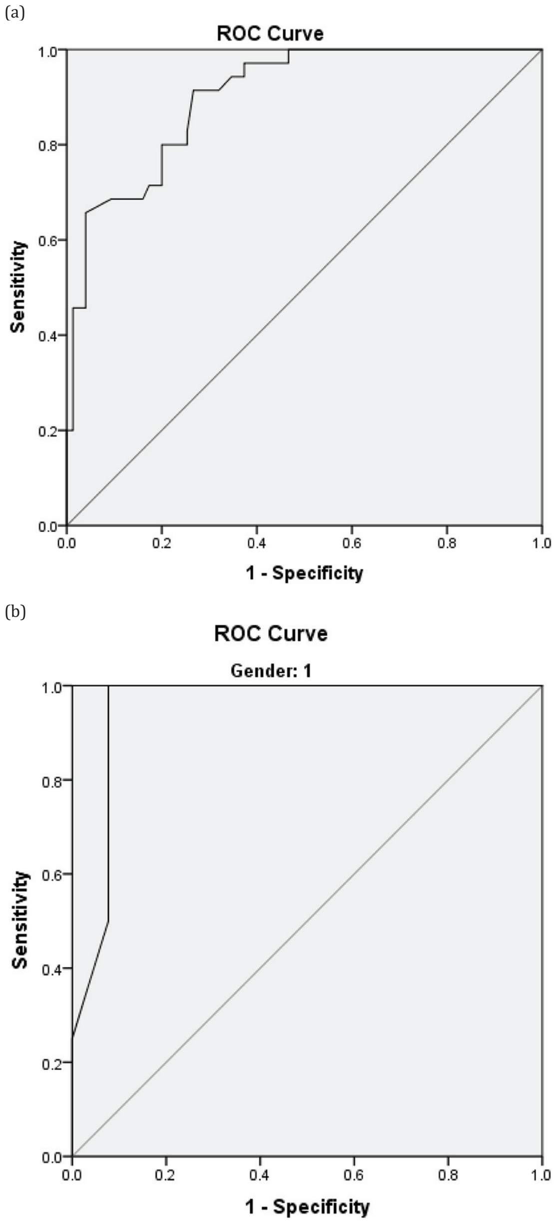

Figure 1. Receiver operating characteristic curves for predicting low muscle mass using calf circumference in (a) female and (b) male.

CC. The optimal CC cut-off values for predicting low muscle mass was 34.0 (sensitivity 85.5%, specificity 71.8%) with 0.895 AUC ($p<0.05$, 95% confidence interval [CI] 0.830 to 0.959). Figure 1b shows the ROC curve for male CC with the optimal cut-off values for predicting low muscle mass at 33.4 (sensitivity 75.0%, specificity 92.3%) with 0.952 AUC ($p<0.05$, 95% CI 0.830 to 0.959). Figure 2 presents the linear relationship between CC and

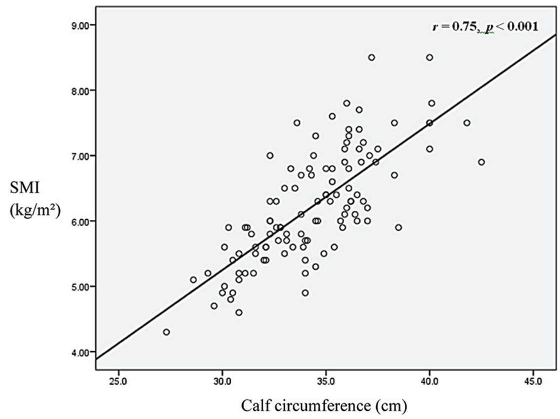

Figure 2. The relationship between calf circumference and SMI measured by the BIA.

SMI with the correlation coefficient (r) equal to 0.75 ($p<0.001$).

For multiple linear regression analysis, fat mass and BMI were withdrawn from the predictive equation, because the limitation of fat mass evaluation in several public hospitals and BMI also had multicollinearity with weight, fat mass, and CC. Then, the remainders that affected the prediction of SMI were studied using multiple linear regression analysis with forward stepwise procedure. Table 2 demonstrates that gender, age, weight, and CC significantly affected the prediction of SMI ($p<0.05$).

Then, multiple linear regression analysis was performed using gender, age, weight, and CC as independent variables to predict SMI. The most influential factors were gender, CC, weight, and age, respectively (Table 3). The predictive equation of SMI was as follow: SMI (kg/m^2) = 0.996 × gender (0=women, 1=men) – 0.02 × age (y) + 0.029 × weight (kg) + 0.125 × CC (cm) + 1.462. The adjusted r^2 of the model was 0.80 and the standard error of the estimate was 0.39 kg/m^2.

Discussion

In the present study, the prevalence of low muscle mass based on the AWGS 2019 criteria[2] was 31.8% (95% CI 23.3 to 41.4), which men had lower prevalence than women at 23.5% versus 33.3%, respectively. Consistently, the study of Khongsri et al[19] reported the prevalence of low muscle mass in Thai elderly was 30.5% (95% CI 25.0 to 36.5%), which was close to the present study results. However, men had more prevalence than women at 33.9% versus 29.3%, respectively.

The optimal CC cut-off values for predicting low

Table 2. Factors associated with SMI using multiple linear regression analysis

Factors	Unstandardized coefficients		p-value	95% CI for B	
	B	Standard error		Lower bound	Upper bound
Constant	1.390	0.829	0.097	–0.256	3.036
Age	–0.018	0.006	0.007*	–0.031	–0.005
Weight	0.030	0.007	<0.001*	0.016	0.045
Sex: male	1.015	0.128	<0.001*	0.762	1.269
Use of statins	0.005	0.081	0.956	–0.156	0.165
Non-smoker	–0.032	0.273	0.907	–0.573	0.509
Ex-smoker	–0.069	0.304	0.822	–0.672	0.535
Non-drinking	0.057	0.299	0.848	–0.535	0.650
Moderate drinking	0.116	0.303	0.701	–0.484	0.717
Low level of physical activity	–0.252	0.205	0.221	–0.658	0.154
Moderate level of physical activity	–0.222	0.138	0.111	–0.495	0.052
Calf circumference	0.126	0.022	<0.001*	0.081	0.170

CI=confidence interval

Dependent variable: SMI

Current smoker, heavy drinking and high level of physical activity were the references

* p<0.05 significant

Table 3. Factors used to generate the equation using multiple linear regression analysis

Factors	Unstandardized coefficients		Standardized coefficients (B)	p-value	95% CI for B	
	B	Standard error			Lower bound	Upper bound
Constant	1.462	0.695		0.038	0.084	2.840
Sex	0.996	0.106	0.420	<0.001*	0.785	1.206
Age	–0.020	0.006	–0.152	0.001*	–0.032	–0.008
Weight	0.029	0.007	0.311	<0.001*	0.016	0.043
Calf circumference	0.125	0.021	0.416	<0.001*	0.082	0.167

CI=confidence interval

* p<0.05 significant

muscle mass in male and female were consistent with the recommendation from the AWGS 2019[25]. The authors also found the strong correlation between CC and SMI measured by the BIA (r=0.75). The results corresponded to the study of Ishii et al[9] among community-dwelling Japanese elderly. They found that CC had a high relationship with SMI in both men and women (r=0.78, 0.75, respectively)[9]. Similarly, Hwang et al[11] showed that CC had a positive correlation with SMI (r=0.81 in men, r=0.75 in women) among community-dwelling Taiwanese elderly. Therefore, CC could be used as a screening tool to identify skeletal muscle mass in community-dwelling elderly. The present study data supported the AWGS 2019 recommendation to screen low muscle mass using CC measurement[2].

Other anthropometric measurements were also proposed as the indices for muscle mass evaluation, such as upper arm circumference or thigh muscle measurement. Tresignie et al[26] revealed that the whole body fat mass had a high relationship with upper arm circumference, but not for CC (r=0.67 in male, r=0.78 in female). Moreover, the study of Abe et al[25] demonstrated that moderate to high levels of physical activity, measured by an accelerometer, corresponded well with the increased calf muscle, however, no relationship was observed between physical activity level and thigh muscle. Consequently, CC could be superior to others as a representative of appendicular muscle mass.

For multicollinearity and multiple linear regression analyses, the major factors including gender, age, weight, and CC significantly affected the predicted SMI. In addition to CC, weight also had a direct effect on muscle mass because people with low body weight tended to have inadequate nutrition and energy to build their muscle mass, which was in agreement with the previous studies[8-12,18,19]. The authors also found that age was inversely related to this index. Increasing age correlated with low muscle mass, which was consistent with the previous studies[13,14,17,19,20]. The peak maximum of muscle mass occurs before the age of 40, after that, muscle mass would gradually decrease about 8% every 10 years[17]. At the age of 70, the rate of decline could remarkably increase to 15%[17]. This could be explained by physiologic conditions in the elderly, when there are changes in anabolic hormones such as testosterone and growth hormones depletion[17]. Moreover, aging increases free radicals that cause mitochondria to produce less energy resulting in a higher rate of muscle cell death[27]. The present study also found that women tended to have lower SMI than men, which could be explained from the difference in testosterone levels between the genders[14]. The present study affirmed that the influential factors to the declining of muscle mass were gender, CC, weight, and age, respectively and the adjusted r^2 of the equation was 0.80.

The current study revealed the relationship between CC and BIA-measured SMI among community-dwelling Thai elderly in non-hospital setting, which could reflect the usefulness of CC measurement for low muscle mass screening in the elderly. It was the first study that elaborated the relationship between the related factors and SMI in the form of the predictive equation in Thailand. It would also be beneficial for further early detection and following-up the treatment in aged-related sarcopenic patients.

Due to the limited number of males in the present study, the authors recommended using the data with precaution as the results needed more male samples to evaluate the accuracy. The selection bias might also occur, as all participants were the elderly in Sriracha at only one community, therefore, the results might not be generalized to the elderly in other areas or represented the older adults of the whole country.

Accuracy and validity testing should be further confirmed for the SMI predictive equation in the large-scale study. The relationship between CC and SMI categorized by gender is also needed, as gender significantly affected the SMI. Additionally, the study in other populations, for example, patients admitted in the hospital or lived in the nursing home, might be beneficial for more inclusive findings.

Conclusion

CC was positively correlated with BIA-measured SMI and could be used as a screening tool to identify the community-dwelling Thai elderly with low muscle mass. Major predictors of SMI were age, gender, weight, and CC.

Acknowledgement

The present study was accomplished with the support of all the staffs from Queen Savang Vadhana Memorial Hospital and the Institute of nutrition, Mahidol University. The authors would like to show their gratitude towards Phonpen Akarawatcharangura Goo, MD. for her advice on research methodology, as well as Dr. Chuenrutai Yeekian for her advice on the application of medical statistics and statistical analysis programs.

Funding disclosure

The present research was supported by Queen Savang Vadhana Memorial Hospital.

Conflicts of interest

All authors have no potential conflicts of interest.

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