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Calf Circumference as a Simple Screening Marker for Diagnosing Sarcopenia in Older Korean Adults: the Korean Frailty and Aging Cohort Study (KFACS)

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ABSTRACT

Background: The purpose of this study was to explore the optimal cut-off point of calf circumference (CC) as a simple proxy marker of appendicular skeletal muscle mass (ASM) and sarcopenia in the Korean elderly and to test the criterion-related validity of CC by analyzing its relationships with the physical function.

Methods: The participants were 657 adults aged 70 to 84 years who had completed both dual energy X-ray absorptiometry (DXA) and physical function test in the first baseline year of the Korean Frailty and Aging Cohort Study.

Results: ASM and skeletal muscle mass index (SMI) were correlated positively with CC (male, ASM, $r = 0.55$ and SMI, $r = 0.54$; female, ASM, $r = 0.55$ and SMI, $r = 0.42$; all $P < 0.001$). Testing the validity of CC as a proxy marker for low muscle mass, an area under the curve (AUC) of 0.81 for males and 0.72 for females were found and their optimal cut-off values of CC were 35 cm for males and 33 cm for females. In addition, CC-based low muscle groups were correlated with physical functions even after adjusting for age and body mass index. Also, the cut-off value of CC for sarcopenia was 32 cm (AUC; male, 0.82 and female, 0.72).

Conclusion: The optimal cut-off values of CC for low MM are 35 cm for males and 33 cm for females. Lower CC based on these cut-off values is related with poor physical function. CC may be also a good indicator of sarcopenia in Korean elderly.

Keywords: Anthropometry; Aged; Muscle Mass; Sarcopenia; Korea

Author Contributions
Conceptualization: Kim S, Won CW. Methodology: Kim S, Kim M. Formal analysis: Kim S. Data curation: Kim S, Kim M. Writing - original draft: Kim S. Writing - review & editing: Kim M, Lee Y, Kim BS, Yoon TY, Won CW.

INTRODUCTION

Sarcopenia, resulting from reduced skeletal muscle mass, is associated with aging. The concept of sarcopenia was first introduced in 1989 by Irwin Rosenberg.[1] Sarcopenia is directly responsible for reduced strength, which elevates the risk of negative outcomes such as decreased physical function, fall, disability, and death.[2-5] Sarcopenia was recently officially classified as a disease and assigned an International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10CM) code in the USA.[6]

In 1998, following the recommendation by Baumgartner et al.,[2] sarcopenia was defined as a lean mass index (ASM/Ht[2]) measured with DXA that fell 2SD below the mean for young and healthy adults. Subsequently, several regions (Europe, USA, and Asia) and organizations incorporated decreased physical performance in the diagnostic criteria.[7-9]

Along with reduced muscle strength and performance, low muscle mass is an essential element for diagnosing sarcopenia. Although diagnostic imaging methods such as computed tomography (CT), magnetic resonance imaging (MRI), and dual energy X-ray absorptiometry (DXA) have been recommended to assess muscle mass, the risk of radiation exposure, need for skilled technicians, and time and budgetary restrictions prohibit their wider adoption across communities or large-scale research projects.[10-12] Based on the need for a simpler method of assessing muscle mass than diagnostic imaging, ongoing studies demonstrating associations between markers and muscle mass have been conducted in community-based, primary care, and large-scale epidemiological contexts. Calf circumference (CC) measurements, which are simple to obtain and noninvasive, have been used as a basic tool for assessing nutritional status. A number of studies have evaluated its adequacy as a proxy for appendicular skeletal muscle mass (ASM).[13-15] However, anthropometric indices including CC tend to vary by age, gender, ethnicity, and environment, making it difficult to determine standard values. Therefore, the predictive accuracy of CC has been debated.[11,16]

The purpose of this study was to explore optimal cut-off values of CC for using as a proxy of ASM in Korean elderly, and to verify the criterion-related validity of CC by analyzing its relationships with sarcopenia and physical function using the first-year baseline data from the Korean Frailty and Aging Cohort Study (KFACS) (an ongoing nationwide cohort study since 2016).

METHODS

Study sample and protocol

The study subjects consisted of older Koreans aged 70 to 84 years who participated in the KFACS, a nationwide cohort study initiated in 2016 to identify and prevent risk factors for frailty among community dwelling elders. KFACS is a multi-center longitudinal study, with 3,000 samples recruited from 10 participating centers across Korean urban, agricultural, and urban countryside communities between 2016 and 2017. In each community, residents who did not plan to relocate outside of the current community within the next 2 years were eligible. Among these, community dwelling elders between 70 and 84 years stratified by age and gender were included for the study.[17] Of the total 1,559 individuals recruited in the first year, 657 individuals whose muscle mass was evaluated using Lunar DXA and who completed the physical performance assessment were included in the present analysis.

Anthropometric measurement methods

Anthropometries were measured using an inelastic tape by investigators trained in standardized measurement methods. To measure the upper arm circumference (UAC), the subject raised the arm at shoulder level with the elbow bent at 90° angle. In this position, the subject flexes the bicep, which can be measured at its greatest girth. To measure CC, the subject stood upright with feet apart shoulder width and body weight evenly distributed between both legs. In this position, CC can be measured at the calf's greatest girth using an inelastic tape measure. To measure waist circumference (WC), the inspector measured participants' the midpoint of lower end of the last rib and the upper ridge of the iliac crest. Body composition was measured using DXA (GE Medical Systems Lunar, Madison, WI, USA). DXA was used to obtain ASM and the fat masses of the four limbs, and skeletal muscle mass index (SMI) was calculated as ASM divided by height squared.

Physical performance and strength measurement

A digital hand grip gauge (Takei TKK 5401, Takei Scientific Instruments, Tokyo, Japan) was used to measure hand grip strength (HGS). The grip strength of each hand was measured once, one at a time. Following a 3-minute wait, a second round of measurement was performed. The highest value for each hand was included in the analysis. To assess balance, gait speed (GS), and sit-to-stand (short physical performance battery, SPPB), and 3-meter time up and go (TUG), existing test guidelines for each procedure were followed.[18] Each item of the SPPB is scored based on a 0 to 4-point scale, with a total score ranging from 0 to 12 points. For GS assessment, the subject walked a total of 7 m at a usual pace, and the time taken to a total of 4 m in the middle (from the 1.5 m point to 5.5 m point) was measured. The test was repeated twice, and the mean of the two trials was used for analysis. For the sit-to-stand test, the subject was timed while performing five cycles of "stand up from and sit down on a chair" as quickly as possible. For the 3-m TUG test, the participant stands up from a chair without armrests and walks 3 m at usual pace, turns at a marker, returns to the chair, and sit down. The TUG time was defined as the time from the start to sit down. To obtain the physical functioning (PF) scale, each subject was personally examined based on a questionnaire consisting of five items: walk the perimeter of a playground (approximately 400 m), climb a flight of stairs (10 steps), bend over forward or squat or kneel, extend the arm to touch an object overhead, and lift an object as heavy as 1.8 L of rice. Each item was scored on a 0 to 3-point scale, and the total score was converted to a 100-point scale. The closer the total score approached 100 points, the greater the subject's physical function.[19]

Definitions of sarcopenia

According to the criteria established by the Asian Working Group for Sarcopenia (AWGS), sarcopenia was defined as low muscle function (HGS of < 26 kg for males and < 18 kg for females and/or GS of < 0.8 m/s for both sex) plus low muscle mass (SMI of < 7.0 kg/m² for males and for females < 5.4 kg/m²). Additionally, Korean Instrumental Activities of Daily Living (K-IADL) was determined.[9]

Statistical methods

The study subjects' characteristics are presented by sex, as mean ± standard deviation (SD). Statistical significance for continuous variables was verified using a t-test. A Pearson correlation analysis was performed to verify the relationships between anthropometric variables, ASM, and SMI. Receiver operating characteristic (ROC) analysis was performed to explore the cut-off values of CC for males and females and to verify the predictive validity of low SMI measured using DXA.[20] We performed analysis of covariance to verify the

relationships between reduced muscle mass and related changes in physical function. SPSS version 23.0 (IBM Corp., Chicago, IL, USA) was used for statistical analysis, and statistical significance was determined at a *P* value of < 0.05.

Ethics statement

Our research plan was approved by the Institutional Review Board of the Kyung Hee University, and written consent was obtained from each subject prior to commencement of the study (approved No. KMC IRB 2017-09-022).

RESULTS

General characteristics of the participants

The mean age of the 657 participants was 76.2 years (76.5 for males and 75.8 for females), and the mean body weight was 60.3 kg (65.2 kg for males and 57.1 kg for females.) The mean CC of the subjects was 33.2 cm, with males having a higher mean CC than females (34.1 cm for males 32.5 cm for females.) The mean ASM measured using DXA was 19.6 kg for males and 13.7 kg for females, HGS, 32.1 kg for males and 20.5 kg for females, GS 1.3 m/s for males and 1.1 m/s for females indicating a sex difference (**Table 1**). Of the anthropometric indices, ASM and SMI were negatively correlated with age and positively correlated with bodyweight, body mass index (BMI), WC, UAC, and CC (males, ASM $r = 0.55$, SMI, $r = 0.54$; females, ASM, $r = 0.55$, SMI, $r = 0.42$, all $P < 0.001$) (**Table 2**).

Cut-off value of CC for low muscle mass and sarcopenia

ROC analysis was performed to confirm the criterion-related validity of CC for low muscle mass according to the AWGS guideline, and the result identified an area under the curve of 0.81 for males and 0.72 for females (**Fig. 1**).[9] From ROC analysis, the optimal cut off

Table 1. General characteristics of study population

Variables	Total (n = 657)	Male (n = 312)	Female (n = 345)	*P* value
Age, yr	76.2 ± 4	76.5 ± 3.8	75.8 ± 4.1	0.027
Height, cm	157.6 ± 8.7	164.9 ± 5.7	151.1 ± 5	< 0.001
Weight, kg	60.3 ± 9.2	64.7 ± 8.7	56.4 ± 7.8	< 0.001
BMI, kg/m²	24.3 ± 3	23.8 ± 2.9	24.7 ± 3	< 0.001
ASM, kg	16.5 ± 3.6	19.6 ± 2.4	13.7 ± 1.6	< 0.001
ASM/Ht², kg/m²	6.6 ± 0.9	7.2 ± 0.8	6 ± 0.6	< 0.001
ASM/BMI	0.7 ± 0.2	0.8 ± 0.1	0.6 ± 0.1	< 0.001
Leg LM, kg	12.2 ± 2.6	14.5 ± 1.8	10.2 ± 1.3	< 0.001
Leg FM, kg	5 ± 1.8	4.2 ± 1.4	5.7 ± 1.8	< 0.001
Arm LM, kg	4.3 ± 1.1	5.1 ± 0.8	3.5 ± 0.5	< 0.001
Arm FM, kg	1.9 ± 0.8	1.5 ± 0.6	2.3 ± 0.8	< 0.001
WC, cm	87.5 ± 8.4	88.2 ± 8.5	86.9 ± 8.2	0.045
UAC, cm	27.9 ± 3	28.3 ± 2.8	27.5 ± 3.2	0.002
CC, cm	33.2 ± 3	34.2 ± 3	32.4 ± 2.8	< 0.001
HGS, kg	26 ± 7.6	32.1 ± 5.7	20.5 ± 4.1	< 0.001
GS, m/s	1.2 ± 0.3	1.3 ± 0.3	1.1 ± 0.3	< 0.001
SPPB	10.5 ± 1.6	10.8 ± 1.4	10.2 ± 1.8	< 0.001
TUG, sec	10.7 ± 2.8	10.2 ± 2.3	11.2 ± 3.1	< 0.001
IADL	11.9 ± 3.2	13.1 ± 3.6	10.8 ± 2.2	< 0.001
PF scale	79.9 ± 22.9	90.5 ± 15.1	70.2 ± 24.4	< 0.001

Variables presented as means or values with standard deviation. *P* value of t-test for continuous variables.
BMI = body mass index, ASM = appendicular skeletal muscle mass, LM = lean mass, FM = fat mass, WC = waist circumference, UAC = upper arm circumference, CC = calf circumference, HGS = hand grip strength, GS = gait speed, SPPB = short physical performance battery, TUG = time up and go, IADL = instrumental activities of daily living, PF = physical functioning.

Table 2. Correlations between anthropometric variables, ASM, and SMI (ASM/Ht²)

Variables	Total				Male				Female			
	ASM		ASM/Ht²		ASM		ASM/Ht²		ASM		ASM/Ht²	
	r[a]	P	r	P	r	P	r	P	r	P	r	P
Age	−0.07	0.095	−0.05	0.217	−0.25	< 0.001	−0.18	0.002	−0.24	< 0.001	−0.10	0.060
Height	0.82	< 0.001	0.49	< 0.001	0.50	< 0.001	−0.06	0.265	0.49	< 0.001	−0.06	0.262
Weight	0.73	< 0.001	0.65	< 0.001	0.78	< 0.001	0.64	< 0.001	0.63	< 0.001	0.40	< 0.001
BMI	0.17	< 0.001	0.37	< 0.001	0.58	< 0.001	0.73	< 0.001	0.46	< 0.001	0.50	< 0.001
WC	0.32	< 0.001	0.36	< 0.001	0.51	< 0.001	0.51	< 0.001	0.38	< 0.001	0.29	< 0.001
UAC	0.37	< 0.001	0.38	< 0.001	0.56	< 0.001	0.52	< 0.001	0.41	< 0.001	0.31	< 0.001
CC	0.54	< 0.001	0.54	< 0.001	0.55	< 0.001	0.54	< 0.001	0.55	< 0.001	0.42	< 0.001

ASM = appendicular skeletal muscle mass, SMI = skeletal muscle mass index, BMI = body mass index, WC = waist circumference, UAC = upper arm circumference, CC = calf circumference.
[a]r = Pearson's correlation coefficient.

value, statistically defined as the best compromise between sensitivity and specificity, was 35 cm for males (sensitivity, 92%; specificity, 59%) and 33 cm for females (sensitivity, 83%; specificity, 50%)

ROC analysis was performed to confirm the validity of CC against sarcopenia according to the AWGS, and the result identified an area under the curve of 0.824 for males and 0.722 for females (**Fig. 1**). The optimal CC value from the ROC analysis, statistically defined as the best compromise between sensitivity and specificity, was 32 cm (males, sensitivity 75%, specificity 83%; females, sensitivity 85%, specificity 57%) (**Tables 3** and **4**).

CC and physical function

In the sarcopenia group based on DXA, both males and females were significantly correlated with reduced HGS, GS, SPPB, TUG, and PF. In the sarcopenia group based on CC males, even after adjusting age and BMI, were significantly correlated with muscle function (HGS, GS), physical performance (SPPB, TUG), whereas females in sarcopenia group based on CC were significantly correlated with reduced muscle function (only HGS) and PF (**Table 5**).
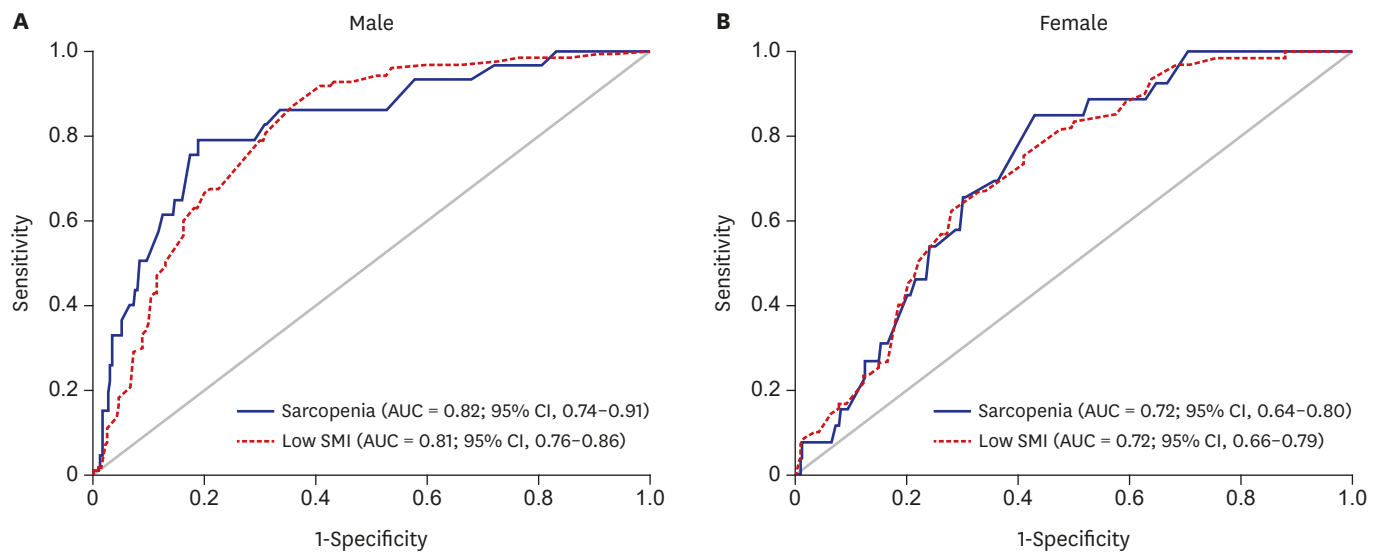

Fig. 1. The receiver operating characteristic curve of CC for low muscle mass and sarcopenia based on the AWGS definition. (**A**) Male, (**B**) Female.
CC = calf circumference, AWGS = Asian Working Group for Sarcopenia, SMI = skeletal muscle mass index, AUC = area under the curve, CI = confidence interval.

Table 3. Sensitivity and specificity of CC measures for low SMI according to AWGS criteria

CC	For low SMI according to AWGS criteria					
	Male			Female		
	Sensitivity	Specificity	Youden index	Sensitivity	Specificity	Youden index
31	-	-	-	52%	78%	0.30
32	-	-	-	73%	60%	0.33
33	49%	87%	0.36	83%	50%	0.34
34	67%	77%	0.45	93%	36%	0.29
35	92%	59%	0.51	-	-	-
36	97%	40%	0.37	-	-	-

Low SMI based on of AWGS guideline (< 7.0 kg/m^2 in [m], < 5.4 kg/m^2 in [f]).
CC = calf circumference, SMI = skeletal muscle mass index, AWGS = Asian Working Group for Sarcopenia.

Table 4. Sensitivity and specificity of CC measures for sarcopenia according to AWGS criteria

CC	For sarcopenia according to AWGS criteria					
	Male			Female		
	Sensitivity	Specificity	Youden index	Sensitivity	Specificity	Youden index
31	-	-	-	54%	75%	0.29
32	75%	83%	0.58	85%	57%	0.42
33	79%	78%	0.57	88%	47%	0.36
34	86%	64%	0.50	92%	33%	0.26
35	93%	42%	0.35	-	-	-

Sarcopenia was defined as low muscle function (HGS of < 26 kg for males and < 18 kg for females and/or GS of < 0.8 m/s for both sex) plus low muscle mass (SMI of < 7.0 kg/m^2 for males and for females < 5.4 kg/m^2).
CC = calf circumference, AWGS = Asian Working Group for Sarcopenia, HGS = hand grip strength, GS = gait speed, SMI = skeletal muscle mass index.

Table 5. Unadjusted and adjusted means (±standard errors) of muscle function, performance, and frailty index according to sarcopenia using AWGS criteria and CC

Sex	Variables	Sarcopenia defined using AWGS			Sarcopenia defined using CC			Sarcopenia defined using CC Age, BMI (after adjusted)		
		No sarcopenia	Sarcopenia	P	CC > 32	CC ≤ 32	P	CC > 32	CC ≤ 32	P
Male	Total, No.	287	33		243	77		243	77	
	HGS	32.8 ± 5.3	24.6 ± 3.5	< 0.001	32.8 ± 5.4	29.3 ± 5.6	< 0.001	32.6 ± 0.3	29.9 ± 0.7	0.001
	GS	1.3 ± 0.3	1.0 ± 0.3	< 0.001	1.3 ± 0.3	1.1 ± 0.3	< 0.001	1.3 ± 0	1.1 ± 0	< 0.001
	SPPB	10.9 ± 1.3	9.9 ± 2.1	< 0.001	10.9 ± 1.3	10.3 ± 1.7	0.001	10.9 ± 0.1	10.4 ± 0.2	0.008
	TUG	10.1 ± 2.2	11.7 ± 2.5	< 0.001	10.0 ± 2.3	10.8 ± 2.2	0.010	10 ± 0.1	10.8 ± 0.3	0.024
	IADL	13.0 ± 3.5	13.8 ± 4.0	0.240	13.1 ± 3.5	13.1 ± 3.8	0.957	13 ± 0.2	13.3 ± 0.5	0.659
	PF	91.5 ± 14.0	82.6 ± 19.0	0.001	90.7 ± 14.3	90.1 ± 16.4	0.745	90.9 ± 1	89.8 ± 1.9	0.624
Female	Total, No.	294	27		169	152		169	152	
	HGS	20.8 ± 3.9	15.5 ± 3.1	< 0.001	21.0 ± 4.0	19.6 ± 4.1	0.001	21.1 ± 0.3	19.6 ± 0.4	0.007
	GS	1.1 ± 0.3	0.9 ± 0.3	< 0.001	1.1 ± 0.2	1.1 ± 0.3	0.019	1.1 ± 0	1.1 ± 0	0.166
	SPPB	10.3 ± 1.7	9.1 ± 2.1	0.002	10.3 ± 1.7	10.0 ± 1.9	0.074	10.3 ± 0.1	10.1 ± 0.2	0.396
	TUG	11.0 ± 3.0	13.3 ± 3.7	< 0.001	10.9 ± 3.0	11.5 ± 3.3	0.073	11 ± 0.3	11.4 ± 0.3	0.384
	IADL	10.7 ± 2.0	11.1 ± 2.4	0.389	10.6 ± 1.8	10.9 ± 2.3	0.204	10.7 ± 0.2	10.8 ± 0.2	0.823
	PF	71.0 ± 24.1	53.0 ± 27.6	< 0.001	73.9 ± 22.6	64.7 ± 26.4	0.001	74.5 ± 2	64 ± 2.1	0.001

Unadjusted and adjusted by age and BMI means ± standard error of variables between sarcopenia and normal group. Analysis of covariance general lineal model with multivariate analysis. Sarcopenia was defined as low muscle function (HGS of < 26 kg for males and < 18 kg for females and/or GS of < 0.8 m/s for both sex) plus low muscle mass (SMI of < 7.0 kg/m^2 for males and for females < 5.4 kg/m^2).
AWGS = Asian working Group for Sarcopenia, CC = calf circumference, SMI = skeletal muscle mass index, HGS = hand grip strength, GS = gait speed, SPPB = short physical performance battery, TUG = time up and go, IADL = instrumental activities of daily living, PF = physical functioning.

DISCUSSION

Measuring CC is a simple and noninvasive assessment method that is easily accessible in communities and primary care settings. World Health Organization (WHO) has suggested the use of CC as a marker of muscle mass in elderly people, and research conducted in 55 European countries has shown that the use of CC as a muscle mass index was more frequent than that of diagnostic imaging, such as DXA or CT in primary care setting.[21,22] However, the cut-off values of CC that are useful for indicating reduced muscle mass can vary by ethnicity

and geographical region. A Japanese study involving community members aged 40–89 years and a Brazilian study of subjects aged 60–69 years both suggested cut-off values of 34 cm for males and 33 cm for females, whereas a French study involving female community members aged ≥ 70 years suggested 31 cm as a cut-off value for diagnosing sarcopenia.[14,15,23] Results of the present study suggest that among elderly community members in Korea, CC and ASM were positively correlated (males, $r = 0.55$, $P < 0.001$; females, $r = 0.55$, $P < 0.001$) and that the appropriate cut-off values of CC denoting reduced muscle mass were 35 cm for males and 33 cm for females.

Considering coefficients between CC and ASM coefficients were slightly lower than those reported in previous Western and Japanese studies, which may be attributed to differences in bone, skin fold, and fat distribution reflected in CC in addition to lower limb muscle mass. Such differences are attributed to sex, ethnicity, genetics, environment, and lifestyle.[14,23-25] Among Asians, fat percentage, particularly subcutaneous fat, is higher in males and females with low BMI.[26] Furthermore, a traditional Korean diet based on carbohydrates (rice and grains) which lacks protein, as well as elderly Korean lifestyles lack sufficient physical activity, tend to promote fat infiltration.[27,28] CC, as an indicator of leg muscle mass and subcutaneous fat, better represents muscle mass when subcutaneous fat is minimal (i.e., individuals with malnutrition, chronic conditions, or cadavers).[15,29] On the other hand, in ambulatory individuals like our participants, the correlation between CC and ASM tends to be weaker.[30,31]

Although the correlation between CC and ASM was relatively weak in the present study, CC was well correlated with physical function. In a previous study by Landi et al.,[32] GS was correlated with CC, but, when adjusted for age and BMI, the correlation disappeared. In the present study, physical functions were correlated with CC. Notably, although the correlation between CC and ASM, SMI among the female participants were weaker in the present study (ASM, $r = 0.55$; SMI, $r = 0.42$), correlations between low CC and physical functions were similar to those observed in the male subjects, or were even stronger in some physical functions. Moreover, the fact that such correlations were stronger in females, who tend to have greater fat mass in the lower limbs than males, is congruent with outcomes reported by previous studies in which lower limb fat, in addition to lower limb muscle mass, is correlated with muscle function.[33,34] Bouchard et al.,[33] showed that fat mass and leg strength, but not muscle mass were independently predicting physical function in older men and women. Kuyumcu et al.,[34] demonstrated that HGS was more strongly correlated with subcutaneous fat in calf, compared with gastrocnemius thickness using ultrasonography.

The existing European sarcopenia diagnostic criteria do not recommend CC as an indicator of muscle mass because CC measurements are prone to errors.[8] However, based on our results, CC may be treated as an indicator of reduced muscle mass and physical function in Korean elders (**Fig. 1**). Therefore, CC may be a good indicator of sarcopenia in Korean elders. A prospective longitudinal study would be needed to confirm the correlation between CC and physical function.

Although we used ASM measurements using DXA, the gold standard methods of body composition measurement are not DXA but MRI and CT. Therefore, a reference method bias may be present.[8,35] Although we only included the data from the 4 centers using Lunar DXA, there is still the limitation of not having used the same model in all 4 centers. However, each center carried out their own quality control in order to minimize the differences between the centers.

Furthermore, because this is a cross-sectional study, a follow-up longitudinal study investigating the predictive validity of CC for physical functions should be conducted. Since calf size was measured only once in this study, we cannot show the correlation for duplicated measurements. Nevertheless, we trained the examiners and tried to increase reliability by allowing them to participate in the study only after passing through a performance test.

Nevertheless, this study is the first to suggest a cut-off value of CC for Korean elders, indicated CC is a good proxy marker of reduced muscle mass and may be related with physical function of individuals who represent the 70 to 85-year-olds residing in communities in Korea. Furthermore, CC may be a good indicator of sarcopenia in Korean community-dwelling older adults.

The cut-off values of CC for use as indicators of reduced muscle mass are 35 cm for males and 33 cm for females in community-dwelling Korean elders. Reduced muscle mass, based on these cut-off values, is correlated with physical function. Therefore, CC appears to be a proxy marker for muscle mass measured using DXA and may serve as a potential screening tool for sarcopenia.

REFERENCES

1. Rosenberg IH. Sarcopenia: origins and clinical relevance. *J Nutr* 1997;127(5):990S-991S.
   PUBMED | **CROSSREF**

2. Baumgartner RN, Koehler KM, Gallagher D, Romero L, Heymsfield SB, Ross RR, et al. Epidemiology of sarcopenia among the elderly in New Mexico. *Am J Epidemiol* 1998;147(8):755-63.
   PUBMED | **CROSSREF**

3. Newman AB, Kupelian V, Visser M, Simonsick E, Goodpasr B, Nevitt M, et al. Sarcopenia: alternative definitions and associations with lower extremity function. *J Am Geriatr Soc* 2003;51(11):1602-9.
   PUBMED | **CROSSREF**

4. Janssen I, Heymsfield SB, Ross R. Low relative skeletal muscle mass (sarcopenia) in older persons is associated with functional impairment and physical disability. *J Am Geriatr Soc* 2002;50(5):889-96.
   PUBMED | **CROSSREF**

5. Rantanen T, Volpato S, Ferrucci L, Heikkinen E, Fried LP, Guralnik JM. Handgrip strength and cause-specific and total mortality in older disabled women: exploring the mechanism. *J Am Geriatr Soc* 2003;51(5):636-41.
   PUBMED | **CROSSREF**

6. Cao L, Morley JE. Sarcopenia is recognized as an independent condition by an International Classification of Disease, Tenth Revision, Clinical Modification (ICD-10-CM) Code. *J Am Med Dir Assoc* 2016;17(8):675-7.
   PUBMED | **CROSSREF**

7. Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, et al. Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. *J Am Med Dir Assoc* 2011;12(4):249-56.
   PUBMED | **CROSSREF**

8. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 2010;39(4):412-23.
   PUBMED | **CROSSREF**

9. Chen LK, Liu LK, Woo J, Assantachai P, Auyeung TW, Bahyah KS, et al. Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. *J Am Med Dir Assoc* 2014;15(2):95-101.
   PUBMED | **CROSSREF**

10. Cooper C, Fielding R, Visser MV, Van Loon LJ, Rolland Y, Orwoll E, et al. Tools in the assessment of sarcopenia. *Calcif Tissue Int* 2013;93(3):201-10.
    PUBMED | **CROSSREF**

11. Mijnarends DM, Meijers JM, Halfens RJ, ter Borg S, Luiking YC, Verlaan S, et al. Validity and reliability of tools to measure muscle mass, strength, and physical performance in community-dwelling older people: a systematic review. *J Am Med Dir Assoc* 2013;14(3):170-8.
    PUBMED | **CROSSREF**

12. Shih R, Wang Z, Heo M, Wang W, Heymsfield SB. Lower limb skeletal muscle mass: development of dual-energy X-ray absorptiometry prediction model. *J Appl Physiol* 2000;89(4):1380-6.
    PUBMED | CROSSREF

13. Halil M, Ulger Z, Varli M, Döventas A, Oztürk GB, Kuyumcu ME, et al. Sarcopenia assessment project in the nursing homes in Turkey. *Eur J Clin Nutr* 2014;68(6):690-4.
    PUBMED | CROSSREF

14. Kawakami R, Murakami H, Sanada K, Tanaka N, Sawada SS, Tabata I, et al. Calf circumference as a surrogate marker of muscle mass for diagnosing sarcopenia in Japanese men and women. *Geriatr Gerontol Int* 2015;15(8):969-76.
    PUBMED | CROSSREF

15. Rolland Y, Lauwers-Cances V, Cournot M, Nourhashémi F, Reynish W, Rivière D, et al. Sarcopenia, calf circumference, and physical function of elderly women: a cross-sectional study. *J Am Geriatr Soc* 2003;51(8):1120-4.
    PUBMED | CROSSREF

16. Perissinotto E, Pisent C, Sergi G, Grigoletto F, Enzi G. Anthropometric measurements in the elderly: age and gender differences. *Br J Nutr* 2002;87(2):177-86.
    PUBMED | CROSSREF

17. Won CW, Lee Y, Choi J, Kim KW, Park Y, Park H, et al. Starting construction of frailty cohort for elderly and intervention study. *Ann Geriatr Med Res* 2016;20(3):114-7.
    CROSSREF

18. Guralnik JM, Ferrucci L, Pieper CF, Leveille SG, Markides KS, Ostir GV, et al. Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *J Gerontol A Biol Sci Med Sci* 2000;55(4):M221-31.
    PUBMED | CROSSREF

19. Lee YH, Lee KJ, Han GS, Yoon SJ, Lee YK, Kim CH, et al. The development of physical functioning scale for community-dwelling older persons. *Korean J Prev Med* 2002;35(4):359-74.

20. Youden WJ. Index for rating diagnostic tests. *Cancer* 1950;3(1):32-5.
    PUBMED | CROSSREF

21. World Health Organization. *Physical Status: the Use and Interpretation of Anthropometry: Report of a WHO Expert Committee*. Geneva, Switzerland: World Health Organization; 1995.

22. Bruyère O, Beaudart C, Reginster JY, Buckinx F, Schoene D, Hirani V, et al. Assessment of muscle mass, muscle strength and physical performance in clinical practice: an international survey. *Eur Geriatr Med* 2016;7(3):243-6.
    CROSSREF

23. Barbosa-Silva TG, Bielemann RM, Gonzalez MC, Menezes AM. Prevalence of sarcopenia among community-dwelling elderly of a medium-sized South American city: results of the COMO VAI? study. *J Cachexia Sarcopenia Muscle* 2016;7(2):136-43.
    PUBMED | CROSSREF

24. Ishii S, Tanaka T, Shibasaki K, Ouchi Y, Kikutani T, Higashiguchi T, et al. Development of a simple screening test for sarcopenia in older adults. *Geriatr Gerontol Int* 2014;14 Suppl 1:93-101.
    PUBMED | CROSSREF

25. Roubenoff R. Sarcopenic obesity: does muscle loss cause fat gain?: lessons from rheumatoid arthritis and osteoarthritis. *Ann N Y Acad Sci* 2000;904(1):553-7.
    PUBMED | CROSSREF

26. Rush EC, Freitas I, Plank LD. Body size, body composition and fat distribution: comparative analysis of European, Maori, Pacific Island and Asian Indian adults. *Br J Nutr* 2009;102(4):632-41.
    PUBMED | CROSSREF

27. Song Y, Joung H. A traditional Korean dietary pattern and metabolic syndrome abnormalities. *Nutr Metab Cardiovasc Dis* 2012;22(5):456-62.
    PUBMED | CROSSREF

28. Sin MK, Choe MA, Kim J, Chae YR, Jeon MY, Vezeau T. Comparison of body composition, handgrip strength, functional capacity, and physical activity in elderly Koreans and Korean immigrants. *Res Gerontol Nurs* 2009;2(1):20-9.
    PUBMED | CROSSREF

29. Martin AD, Spenst LF, Drinkwater DT, Clarys JP. Anthropometric estimation of muscle mass in men. *Med Sci Sports Exerc* 1990;22(5):729-33.
    PUBMED | CROSSREF

30. Chumlea WC, Guo SS, Vellas B, Guigoz Y. Techniques of assessing muscle mass and function (sarcopenia) for epidemiological studies of the elderly. *J Gerontol A Biol Sci Med Sci* 1995;50 Spec No:45-51.
    PUBMED

31. Heymsfield SB, Gonzalez MC, Lu J, Jia G, Zheng J. Skeletal muscle mass and quality: evolution of modern measurement concepts in the context of sarcopenia. *Proc Nutr Soc* 2015;74(4):355-66.
   PUBMED | **CROSSREF**

32. Landi F, Onder G, Russo A, Liperoti R, Tosato M, Martone AM, et al. Calf circumference, frailty and physical performance among older adults living in the community. *Clin Nutr* 2014;33(3):539-44.
   PUBMED | **CROSSREF**

33. Bouchard DR, Héroux M, Janssen I. Association between muscle mass, leg strength, and fat mass with physical function in older adults: influence of age and sex. *J Aging Health* 2011;23(2):313-28.
   PUBMED | **CROSSREF**

34. Kuyumcu ME, Halil M, Kara Ö, Çuni B, Çağlayan G, Güven S, et al. Ultrasonographic evaluation of the calf muscle mass and architecture in elderly patients with and without sarcopenia. *Arch Gerontol Geriatr* 2016;65:218-24.
   PUBMED | **CROSSREF**

35. Toombs RJ, Ducher G, Shepherd JA, Souza MJ. The impact of recent technological advances on the trueness and precision of DXA to assess body composition. *Obesity (Silver Spring)* 2012;20(1):30-9.
   PUBMED | **CROSSREF**