Journals of Gerontology: MEDICAL SCIENCES
Cite journal as: J Gerontol A Biol Sci Med Sci 2014 October;69(10):1244–1252
doi:10.1093/gerona/glu050

Advance Access publication April 10, 2014

Sarcopenia: An Independent Predictor of Mortality in Community-Dwelling Older Korean Men

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Background. The concept of sarcopenia has expanded recently to include muscle strength or physical performance. We investigated whether the Europe Working Group on Sarcopenia in Older People (EWGSOP) definition of sarcopenia predicts the risk of all-cause mortality in community-dwelling older adults.

Methods. This study included 284 men and 272 women aged 65 and older. The outcome was all-cause mortality during the 6-year follow-up period. We defined sarcopenia based on the EWGSOP definitions of sarcopenia: height (ht)- or weight (wt)-adjusted appendicular skeletal muscle mass (ASM/ht^2 or ASM/wt) assessed by dual-energy x-ray absorptiometry, leg muscle strength, and short physical performance battery test score.

Results. During the 6-year follow-up, 40 men and 19 women died. The risk of death was 2.99 times and 3.22 times higher in men with sarcopenia identified by ASM/ht^2 and ASM/wt, respectively, compared with nonsarcopenic men. The hazard ratio for death was 5.37 for men with weak leg muscle strength. Men with a low short physical performance battery score had a 3.15 times higher risk of death compared with those with high short physical performance battery scores, even after adjusting for all covariates. The adjusted hazard ratios for EWGSOP-defined sarcopenia were 4.00 for ASM/ht^2 and 6.89 for ASM/wt in men. By contrast, sarcopenia defined by these criteria was not associated with a higher risk of death in women.

Conclusions. Our data suggest that, in older men, EWGSOP-defined sarcopenia is related to higher mortality compared with nonsarcopenia regardless of the ASM/ht^2 or ASM/wt index. In older women, further studies with large sample sizes are needed to assess whether EWGSOP-defined sarcopenia increases the mortality risk.

Key Words: Sarcopenia—Body composition—Epidemiology—Functional performance.

Received October 24, 2013; Accepted March 11, 2014

Decision Editor: Stephen Kritchevsky, PhD

SARCOPENIA is defined as a syndrome that is associated with muscle mass loss alone or in combination with increased fat mass with aging (1,2). A growing body of research indicates that sarcopenia can contribute to functional impairment, the metabolic syndrome, cardiovascular disease, and the risk of death in the elderly people (3–10).

There are several problems related to research on the outcomes of sarcopenia. One major problem is the definition of sarcopenia. In early studies, the definition of sarcopenia focused on muscle mass. The most widely accepted definition in use today was proposed by Baumgartner and coworkers (11) as the appendicular skeletal muscle mass (ASM), measured by dual-energy x-ray absorptiometry (DXA), divided by height squared, which gives ASM/ht^2. However, ASM/ht^2 has a limitation in identifying sarcopenia in obese people because this variable correlates with body mass index (BMI). Another two indices have been suggested: skeletal muscle mass/body weight measured by bioelectrical impedance analysis and fat mass–adjusted ASM (6,12). However, bioelectrical impedance analysis is not as accurate as DXA for measuring muscle mass. In addition, the fat mass–adjusted ASM is based on the residuals obtained from linear regression of ASM on height and fat mass, and it is difficult to use in practice.

The definition of sarcopenia has evolved recently from a focus on muscle mass to muscle strength and physical function. Although muscle mass largely influences muscle strength, muscle strength and function begin to decline before muscle mass decreases (13,14). The decline in muscle strength has been reported as a stronger independent risk factor for mortality compared with muscle mass (9,15).

Considering the recent evolution of the sarcopenia concept, it is important to determine which definition of sarcopenia is related to the risk of mortality.

Another issue in defining sarcopenia is that the cutoff point of each muscle-related parameter has not been established (2). The definitions of muscle-related parameters need to be redefined within each ethnic group to reflect an individual's health outcome. In this context, the cutoff points of muscle-related parameters should be evaluated based on outcome measures such as metabolic impairment, physical disability, and mortality.

Recently, the Europe Working Group on Sarcopenia in Older People (EWGSOP) suggested a definition of sarcopenia as low muscle mass with weak muscle strength or poor physical performance (2). However, the cutoff points of the EWGSOP sarcopenia criteria were based on the white population. The EWGSOP-suggested definition of sarcopenia should be evaluated for its clinical implications in other populations, including the Asian population.

To our knowledge, only two studies have used the composite definition of sarcopenia including muscle mass and muscle strength or physical performance as a mortality predictor (9,10). These previous studies used the mid-arm or calf muscle circumference and handgrip strength. No studies have investigated the relationship between EWGSOP-defined sarcopenia (ie, DXA-measured ASM and leg muscle strength) and mortality in Asia. The aim of our study was to assess the relationship between the EWGSOP definition of sarcopenia using DXA-measured ASM and leg muscle strength and mortality in a community-based elderly cohort.

Methods

Study Participants

This study was a part of the Korean Longitudinal Study on Health and Aging (KLoSHA), an ongoing population-based observational study initiated in September 2005 in residents aged 65 or older in Seongnam, Korea. The total population of Seongnam was 977,166 in 2004 and the proportion of people aged ≥65 was 6.2% (n = 60,584). Participants were selected using age and sex-stratified random sampling from a roster or people aged 65 and older in Seongnam during August 2005 and invited to participate in the study by letter and telephone. In total, 439 men and 561 women agreed to participate in the study (16). Of this group, 284 men and 272 women who performed all muscle measures were included in the final analysis. The study protocol was approved by the Institutional Review Board of Seoul National University Bundang Hospital. Participants or their legal guardians were fully informed about study participation.

Muscle Mass

Skeletal muscle mass was measured by DXA (Lunar Corporation, Madison, WI). ASM was calculated as the sum of the lean soft tissue mass in the arms and legs. We used two muscle mass–related parameters derived from DXA measures. The first was ASM divided by height squared (ASM/ht^2 in kg/m^2) (11). The ASM/ht^2 index was identical to Baumgartner's, but the cutoff points were generated from our own young Korean adults. The cutoff points of sarcopenia using ASM/ht^2 were 7.09 kg/m^2 in men and 5.27 kg/m^2 in women (4). The other was ASM as a percentage of body weight (ASM/wt) (4). The cutoff points of sarcopenia using ASM/wt were 29.9% in men and 25.1% in women (4).

Leg Muscle Strength

Isokinetic knee extensor muscle strength was measured using an isokinetic device at an angular velocity of 60°/s (Biodex Medical Systems, Shirley, NY). Participants performed two sets of five repetitions, with a 30-second rest between sets, by exerting maximum pressure on the isokinetic device through the entire range of movement. The average concentric peak torque values (Nm) obtained from five torque-angle curves for each set was recorded as the leg muscle strength. The cutoff point for leg muscle strength divided by body weight was 0.75 Nm/kg for men and 0.79 Nm/kg for women; these values were derived using the maximally selected χ^2 statistics method.

Short Physical Performance Battery Test

The short physical performance battery (SPPB) test was used to assess lower extremity performance. A total possible score of 12 was created by summing the score (maximum of 4) for each test: chair stand, gait speed, and standing balance. Functional limitation was defined as an SPPB score of ≤8. Participants were first asked to balance in a standing position with their feet side by side, semi-tandem, and fully tandem for 10 seconds each. Participants were next asked to walk a distance of 4 m at their usual pace. Finally, participants were asked to stand from a sitting position in a chair and return to the seated position five times as quickly as possible while keeping the arms folded across the chest (17).

Definition of Sarcopenia

The EWGSOP recommends the use of the presence of both low muscle function (strength or performance) and low muscle mass for the diagnosis of sarcopenia (2). Following the EWGSOP algorithm, we identified sarcopenic participants as indicated in Figure 1.

Mortality

Deaths were ascertained by an annual follow-up telephone call and were confirmed using the National Death Registry over the 6-year period after the baseline visit. Follow-up duration was defined as the period from the baseline visit until the time of death using the date of death or the end of the follow-up.

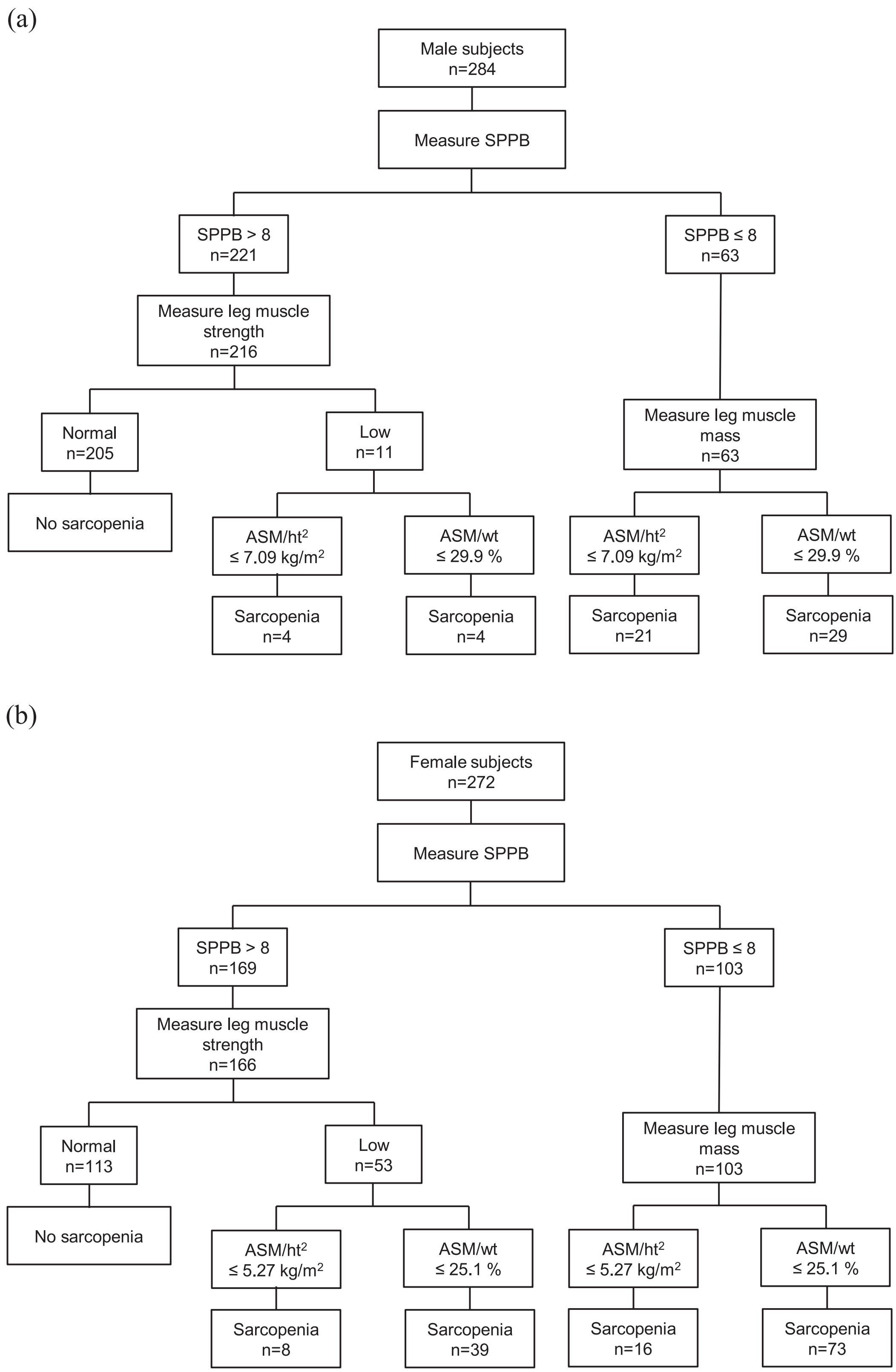

Figure 1. The algorithm to define the Europe Working Group on Sarcopenia in Older People–suggested sarcopenic criteria in (**a**) men and (**b**) women.

Covariates

Height and body weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, with participants wearing light garments. The cutoff point of BMI for obesity was 25 kg/m^2 in both men and women. Waist circumference (WC) was measured at the narrowest point between the lower limit of the ribcage and the iliac crest. The cutoff point of WC for obesity was 87 cm in men and 85 cm in women (18). Fat mass and percentage fat mass (fat mass/body weight) was measured by DXA. We compared participants within the lowest two quintiles with those within the highest three quintiles.

At the baseline visit, adjudicated comorbidities including diabetes, hypertension, cardiovascular disease, stroke, and osteoarthritis were based on self-report, clinical diagnosis, and medication use. Physical activity levels were estimated by summing the time spent walking, gardening, woodworking, lifting, or shoveling over a 24-hour period. The Mini Mental State Examination in the Korean version was used to assess cognitive performance (score, 0–30) (19).

Statistical Analysis

Baseline characteristics were compared between nonsarcopenic and sarcopenic participants using an unpaired *t* test for continuous variables and χ^2 test or Fischer's exact test for categorical variables. The Cox proportional-hazards model and Kaplan–Meier survival curves were used to assess the relationship between sarcopenia and mortality. Model 1 produced unadjusted hazard ratios (HRs) and 95% confidence intervals of the sarcopenia-related parameters that predicted mortality. HRs adjusted for age and BMI, and additional covariates such as diabetes mellitus, hypertension, cardiovascular disease, stroke, physical activity score, and Mini Mental State Examination score were produced by Models 2 and 3, respectively. A log-rank test was applied to test for equality of survival between the sarcopenic and nonsarcopenic groups. All analyses except the maximal χ^2 method were performed using the SPSS 16.0 package (IBM Corporation, Armonk, NY). Maxstat, a maximal χ^2 method in R 2.13.0 (R Development Core Team, Vienna, Austria, http://www.R-project.org), was used to identify optimal cutoff points for leg muscle strength to predict mortality. A *p* value <.05 was considered significant.

Results

During the 6-year follow-up, 40 men and 19 women died in this cohort. Table 1 shows the baseline characteristics of the study participants according to the presence and absence of sarcopenia. Using the EWGSOP-ASM/ht^2 index, sarcopenic participants had lower BMI than nonsarcopenic ones. On the other hand, EWGSOP-ASM/wt index–defined sarcopenic participants had higher BMI than nonsarcopenic ones. In men, sarcopenic participants had weaker leg muscle strength than nonsarcopenic ones regardless of sarcopenic indices. However, in women, there was significant difference in leg muscle strength between sarcopenic and nonsarcopenic participants only by the EWGSOP-ASM/wt index, not by the EWGSOP-ASM/ht^2 index. In both genders, sarcopenic participants were more functionally impaired than nonsarcopenic ones using both indices.

We analyzed the data using the EWGSOP-suggested definition of sarcopenia shown in Figure 1. First, we assessed the SPPB score and then evaluated leg muscle strength in participants with an SPPB score >8. We classified into the sarcopenic group if those with an SPPB score ≤8 or with weak leg muscle strength had low muscle mass. In both men and women, the prevalence of sarcopenia was higher when assessed by ASM/wt than by ASM/ht^2. In men, the prevalence values of sarcopenia using EWGSOP-ASM/ht^2 and EWGSOP-ASM/wt were 8.8% (25/284) and 11.6% (33/284), respectively. By contrast, the difference in the prevalence of sarcopenia using EWGSOP-ASM/ht^2 and EWGSOP-ASM/wt was much greater in women: 8.8% (24/272) and 41.2% (112/272), respectively.

Cox regression models were used to quantify the mortality risk for each muscle-related parameter (Table 2). The risk of death was 2.99 and 3.22 times higher in men with sarcopenia identified by ASM/ht^2 and ASM/wt, respectively, compared with nonsarcopenic men. However, after adjusting for age, BMI, and comorbidity, the mortality risk was higher in sarcopenic men identified by ASM/ht^2 than in those identified by ASM/wt. In Model 3, men with leg muscle strength ≤0.75 Nm/kg had a six times higher risk than did those with leg muscle strength >0.75 Nm/kg. Intriguingly, the men with low SPPB scores had a higher risk of death compared with those with high SPPB scores, even after adjusting for all covariates. EWGSOP-defined sarcopenia predicted a higher mortality risk regardless of muscle mass in men (Figure 2). The HR of the EWGSOP-defined sarcopenia was 3.89 for ASM/ht^2 and 6.89 for ASM/wt in men after adjusting for covariates. By contrast, in women classified as sarcopenic by muscle-related parameters, there was no relationship between these parameters and mortality risk. In the univariate analysis, leg muscle strength was inversely related to increased mortality in women, but this relationship was no longer significant after adjusting for age and BMI. Likewise, the SPPB score and the EWGSOP definition had no additional risk for mortality in women.

Cox regression models were applied to assess the contribution of WC, fat mass, percentage fat mass, and BMI to mortality (Table 3). After adjusting for confounding factors, WC, fat mass, percentage fat mass, and BMI did not predict mortality.

Discussion

In this community-based elderly cohort, the sarcopenic men classified by the EWGSOP definition were at significantly higher risk of mortality than the nonsarcopenic group

Table 1. Baseline Characteristics of Study Participants According to the Presence of Sarcopenia

	EWGSOP-ASM/ht²			EWGSOP-ASM/wt		
	Nonsarcopenic (*n* = 259)	Sarcopenic (*n* = 25)	*p* value	Nonsarcopenic (*n* = 251)	Sarcopenic (*n* = 33)	*p* value
Men						
Age (y, range)	71 (65–90)	82 (67–93)	<.001	71 (65–93)	82 (65–92)	<.001
Weight (kg)	67.1 ± 9.2	55.6 ± 9.9	<.001	65.8 ± 9.4	69.9 ± 12.0	.039
Height (cm)	164.8 ± 6.2	162.7 ± 6.6	.140	164.8 ± 6.2	163.8 ± 6.3	.426
BMI (kg/m²)	24.7 ± 2.9	21.0 ± 3.1	<.001	24.2 ± 3.0	26.0 ± 3.7	.006
ASM (kg)	20.4 ± 2.5	16.0 ± 1.5	<.001	20.3 ± 2.6	18.5 ± 2.9	<.001
ASM/ht² (kg/m²)	7.50 ± 0.76	6.02 ± 0.39	<.001	7.43 ± 0.82	6.91 ± 0.87	.001
ASM/wt (%)	31.0 ± 2.9	28.9 ± 3.4	<.001	31.4 ± 2.8	27.0 ± 1.9	<.001
Leg muscle strength (Nm/kg)	1.22 ± 0.37	0.81 ± 0.37	<.001	1.24 ± 0.36	0.76 ± 0.30	<.001
Comorbidity						
Diabetes mellitus	105 (40.1%)	17 (68.0%)	.010	97 (38.3%)	25 (73.5%)	<.001
Hypertension	118 (45.0%)	9 (36.0%)	.409	108 (42.7%)	19 (55.9%)	.197
Cardiovascular disease	18 (6.9%)	1 (4.0%)	1.000	17 (6.7%)	2 (5.9%)	1.000
Stroke	21 (8.0%)	3 (12.0%)	.450	18 (7.1%)	6 (17.6%)	.049
Osteoarthritis	13 (5.0%)	1 (4.0%)	.763	11 (4.3%)	3 (8.8%)	.382
Physical activity score	16.9 ± 6.1	15.8 ± 5.5	.409	17.0 ± 6.4	15.0 ± 3.0	.003
SPPB score ≤8	42 (16.2%)	21 (84.0%)	<.001	34 (13.5%)	29 (87.9%)	<.001
MMSE score	23.7 ± 4.4	20.7 ± 4.4	.001	23.8 ± 4.2	20.3 ± 4.7	<.001
	Nonsarcopenic (*n* = 248)	Sarcopenic (*n* = 24)	*p* value	Nonsarcopenic (*n* = 160)	Sarcopenic (*n* = 112)	*p* value
Women						
Age (y, range)	69 (65–89)	72 (65–95)	.283	70 (65–95)	72 (66–86)	.001
Weight (kg)	56.6 ± 7.9	47.3 ± 9.4	<.001	54.5 ± 8.4	57.7 ± 8.4	.005
Height (cm)	151.1 ± 5.2	148.2 ± 5.5	.011	151.3 ± 5.3	150.1 ± 5.4	.082
BMI (kg/m²)	24.9 ± 3.0	21.8 ± 3.0	<.001	23.8 ± 3.0	25.8 ± 3.0	<.001
ASM (kg)	13.9 ± 1.6	10.8 ± 1.0	<.001	13.9 ± 1.9	13.2 ± 1.7	.004
ASM/ht² (kg/m²)	6.06 ± 0.55	4.89 ± 0.47	<.001	6.03 ± 0.63	5.83 ± 0.65	.011
ASM/wt (%)	24.6 ± 2.5	22.8 ± 3.5	.002	25.5 ± 2.5	22.7 ± 1.9	<.001
Leg muscle strength (Nm/kg)	0.86 ± 0.29	0.79 ± 0.26	.328	0.93 ± 0.29	0.73 ± 0.24	<.001
Comorbidity						
Diabetes mellitus	100 (39.5%)	3 (16.7%)	.668	95 (37.5%)	8 (32.0%)	.258
Hypertension	123 (48.6%)	9 (50.0%)	.677	126 (49.8%)	11 (44.0%)	.179
Cardiovascular disease	25 (9.9%)	1 (5.6%)	.623	14 (5.5%)	0 (0.0%)	.415
Stroke	24 (9.5%)	2 (11.1%)	.311	25 (9.9%)	4 (16.0%)	.230
Osteoarthritis	35 (13.5%)	1 (5.3%)	.043	29 (12.7%)	7 (31.8%)	.530
Physical activity score	17.1 ± 6.6	14.9 ± 2.7	.003	17.0 ± 7.1	16.6 ± 5.3	.608
SPPB score ≤8	94 (37.2%)	9 (47.3%)	.004	87 (35.1%)	16 (66.7%)	<.001
MMSE score	23.5 ± 4.9	23.0 ± 5.0	.647	23.9 ± 4.6	22.8 ± 5.1	.079

Notes: ASM = appendicular skeletal muscle mass; BMI = body mass index; EWGSOP = Europe Working Group on Sarcopenia in Older People; ht = height; MMSE = Mini-Mental State Examination; SPPB = short physical performance battery; wt = weight. Data were expressed as median (range), mean ± standard deviation or *n* (%).

regardless of whether the ASM/ht² or ASM/wt was used. However, there was no increased risk in sarcopenic women.

The appropriate index for identifying sarcopenia is controversial. We investigated the relationship between sarcopenia identified using each definition of sarcopenia (ie, muscle mass, muscle strength, and physical performance) to mortality risk. For muscle mass, previous studies using the EWGSOP definitions used the mid-arm or calf muscle circumference (9,10). On the other hand, this study directly compared all-cause mortality between groups identified as sarcopenic using ASM/wt and ASM/ht² derived from DXA-measured ASM. In men, the HR for mortality was slightly higher when sarcopenia was defined by ASM/ht² compared with ASM/wt. Sarcopenic participants defined by ASM/ht² have a higher risk of falls and physical disability (8,20). We have shown previously that ASM/wt relates more closely to the cardiometabolic syndrome than does ASM/ht² (4,7). Therefore, in people with sarcopenia, ASM/ht² and ASM/wt may indicate a higher risk of mortality because of frailty and cardiometabolic syndrome, respectively. However, in men, the HR for mortality was higher for the EWGSOP-ASM/wt compared with the EWGSOP-ASM/ht². It is possible that the combination of ASM/wt and leg muscle strength was a stronger predictor of mortality than was the combination of ASM/ht² and leg muscle strength because ASM/wt conferred additional risk

Table 2. Cox Regression Models of Muscle-Related Parameters Predicting Mortality in Men and Women

	Model 1	Model 2	Model 3
Men			
ASM/ht^2 ≤7.09 kg/m^2	2.99 (1.28–6.99)	3.56 (1.24–10.3)	3.12 (1.08–9.02)
ASM/wt ≤29.9%	3.22 (1.44–7.19)	2.67 (1.10–6.52)	2.70 (1.13–6.43)
Leg muscle strength (≤0.75 Nm/kg)	9.35 (4.12–21.2)	6.10 (2.58–14.5)	6.20 (2.50–15.4)
SPPB score ≤8	5.29 (2.38–11.8)	3.72 (1.60–8.62)	3.46 (1.41–8.46)
EWGSOP-ASM/ht^2	4.78 (1.99–11.5)	4.63 (1.62–13.3)	3.89 (1.28–11.7)
EWGSOP-ASM/wt	8.99 (4.09–19.7)	6.21 (2.62–14.7)	6.89 (2.66–17.8)
Women			
ASM/ht^2 <5.27 kg/m^2	2.39 (0.86–6.67)	1.73 (0.55–5.36)	1.24 (0.32–4.77)
ASM/wt <25.1%	0.44 (0.17–1.16)	0.47 (0.15–1.49)	0.42 (0.09–2.07)
Leg muscle strength (≤0.79 Nm/kg)	3.45 (1.13–10.5)	2.56 (0.78–8.34)	3.05 (0.87–10.7)
SPPB score ≤8	1.59 (0.64–3.91)	0.88 (0.33–2.34)	1.07 (0.37–3.06)
EWGSOP-ASM/ht^2	1.13 (0.26–4.90)	0.86 (0.18–4.01)	1.25 (0.26–5.92)
EWGSOP-ASM/wt	0.90 (0.36–2.23)	1.00 (0.35–2.86)	1.02 (0.34–3.04)

Notes: ASM = appendicular skeletal muscle mass; EWGSOP = Europe Working Group on Sarcopenia in Older People; ht = height; SPPB = short physical performance battery; wt = weight. Data were shown as hazard ratio (95% confidence interval). Model 1, unadjusted; Model 2, adjusted for age + BMI; Model 3, adjusted for Model 2 + diabetes mellitus, hypertension, cardiovascular disease, stroke, osteoarthritis, physical activity score, and Mini-Mental State Examination score.

of cardiometabolic syndrome besides frailty reflected by leg muscle strength.

We used leg muscle strength instead of handgrip strength in the EWGSOP algorithm, which included the presence of both low muscle strength or performance and low muscle mass. Newman and coworkers (21) showed that the association patterns were similar for grip strength and quadriceps strength in both men and women. However, older adults had greater relative loss of lower extremity strength compared with upper extremity strength (13). It is biologically plausible that leg muscle strength reflects physical function better than does handgrip strength. The association between handgrip strength and leg muscle strength was weak in our study cohort (Supplementary Figure 1), and handgrip strength did not predict mortality (data not shown). By contrast, weak leg muscle strength increased the mortality risk markedly in older men.

Physical dysfunction is known to be predictive of falls, fractures, and hospitalizations leading to mortality (17,22,23). The SPPB test has been proven to be a good tool for predicting mortality in older population in the United States and France (22,23). However, the relationship between mortality and the SPPB test score has not been evaluated in Asians. Only one study of elderly Chinese people reported that walking speed was a predictor of death (24). To our knowledge, this study is the first to show that the SPPB test score can be used to identify sarcopenic individuals in an older Asian population.

There was a difference between men and women in the predictors of mortality. In men, muscle mass, muscle strength, and physical performance were all significantly related to mortality. By contrast, in women, the muscle-related parameters were not main factors associated with death. In general, men have greater muscle mass, muscle strength, and physical performance compared with women (8,25). A previous study showed that muscle strength attenuation with weight loss was more severe in men than in women (26). Hence, the effect of muscle loss may be greater in men than in women. Low bioavailable testosterone levels increased the risk for sarcopenia, which had a stronger effect on men than women (27). In fact, the most contributing factor to mortality in women was cognitive impairment presented as Mini Mental State Examination scores in our data. In women, the effect of body composition parameters on mortality outcome was inconclusive in our study.

Our study showed that none of the obesity-related parameters such as WC, fat mass, percentage fat mass, and BMI was a significant risk factor for mortality in men and women. Maximal fat mass is usually reached at 60–70 years of age, and fat measures decline thereafter (28). Thus, in adults older than 65 years, muscle mass might have a stronger effect on the risk of mortality than fat mass. In contrast, in a previous study, BMI was a determinant of transition toward sarcopenia (29). Ethnic differences also may contribute to the relationships between muscle mass, fat mass, and mortality. Compared with the white population, Asians have a smaller body size and less fat mass and lean mass. Therefore, it is conceivable that muscle mass is a major determinant of mortality in elderly Asians.

Of note, we generated our own cutoff points of leg muscle strength for predicting mortality instead of using values from other studies. The optimal cutoff points of leg muscle strength for mortality were determined at the bifurcating point using the maximal χ^2 method. Although this value of leg muscle strength should be validated in other cohorts, we believe that it is appropriate to use ethnic-specific cutoff points in such studies. The strength of our study is that this is the first Korean study to assess the effect of EWGSOP-defined sarcopenia on mortality. There have been several studies regarding sarcopenia in older Korean persons, but none of them have investigated either leg strength or physical performance (30,31).

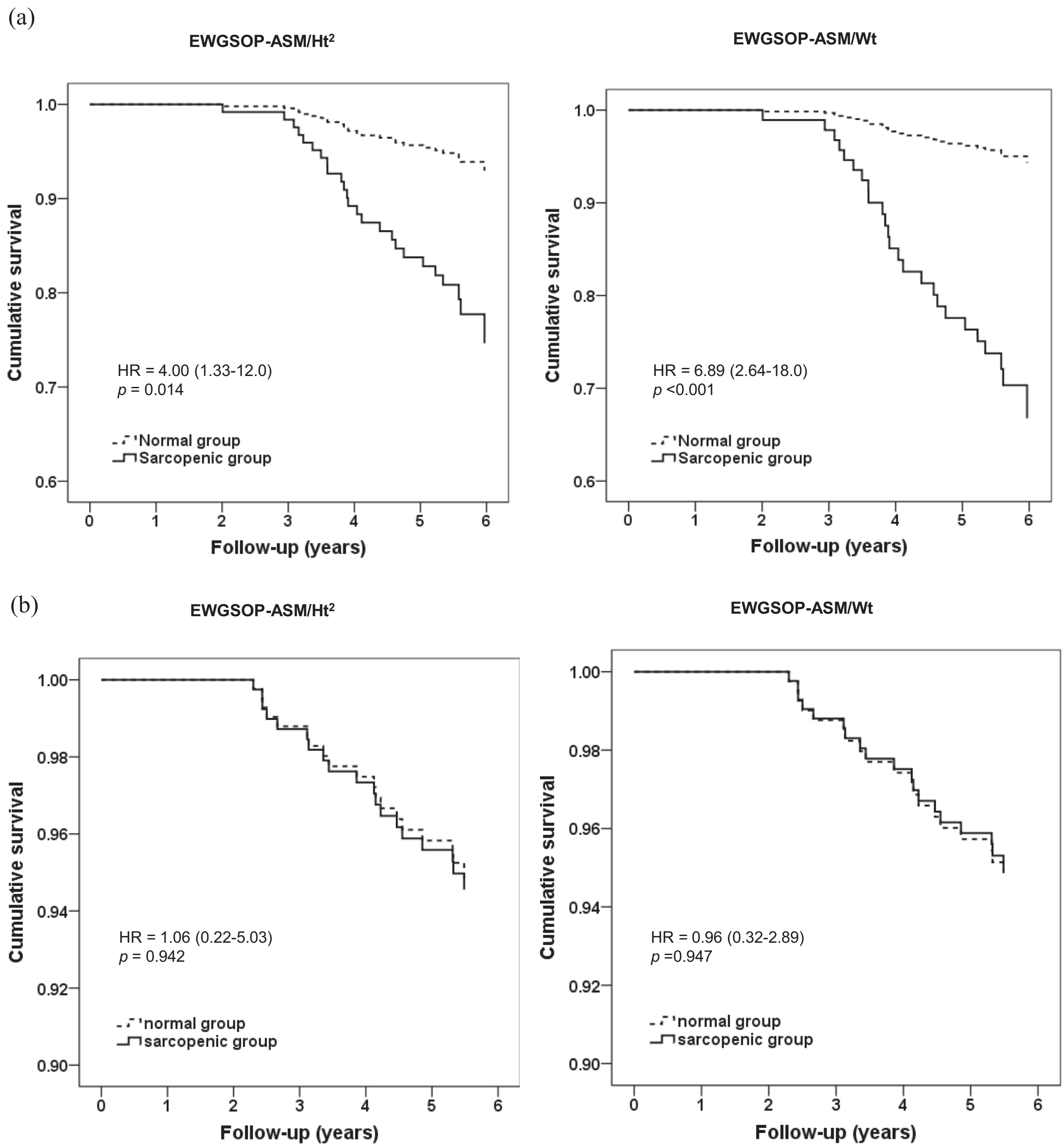

Figure 2. Kaplan–Meier survival curves for mortality according to the Europe Working Group on Sarcopenia in Older People definition of sarcopenia using ASM/ht² or ASM/wt index in (**a**) men and (**b**) women.

Our study has several limitations. The small number of study participants weakened the power of the study. The limited number of deaths makes it hard to reach any conclusion in women. As another clinical end point, we previously showed that sarcopenia increased the risk for functional limitation in both men and women although gender-different muscle indices were used (32). Therefore, if the sample size is large enough, women with sarcopenia may be at higher risk for mortality than those without sarcopenia. Information about cause-specific mortality was not available; therefore, only all-cause mortality was included. Despite these limitations, the strength of our study is that we

Table 3. Cox Regression Models of Adiposity-Related Parameters Predicting Mortality in Men and Women

	Model 1	Model 2	Model 3
Men			
Waist circumference ≥87 cm	1.40 (0.71–2.78)	1.27 (0.64–2.52)	0.97 (0.46–2.06)
Fat mass	0.62 (0.30–1.30)	0.54 (0.21–1.38)	0.87 (0.43–1.78)
Percentage fat mass	2.58 (1.38–4.80)	2.19 (0.97–4.93)	1.40 (0.70–2.79)
BMI ≥25 kg/m^2	0.49 (0.22–1.11)	0.76 (0.33–1.73)	0.79 (0.34–1.88)
Women			
Waist circumference ≥85 cm	0.43 (0.15–1.19)	0.40 (0.12–1.36)	0.74 (0.21–2.57)
Fat mass	0.68 (0.28–1.68)	1.09 (0.35–3.39)	0.59 (0.10–3.30)
Percentage fat mass	0.86 (0.34–2.19)	1.29 (0.42–4.01)	1.03 (0.45–6.95)
BMI ≥25 kg/m^2	0.33 (0.13–0.81)	0.38 (0.15–0.93)	0.64 (0.19–2.18)

Notes: BMI = body mass index. Data were shown as hazard ratio (95% confidence interval). Model 1, unadjusted; Model 2, adjusted for age; Model 3, adjusted for Model 2 + diabetes mellitus, hypertension, cardiovascular disease, stroke, osteoarthritis, physical activity score, and Mini-Mental State Examination score.

measured several muscle-related parameters, such as muscle mass, muscle strength, and physical performance, over a long follow-up period in a community-dwelling cohort.

In conclusion, men with sarcopenia identified by the EWGSOP definition were at significantly higher risk for mortality than were those without sarcopenia, regardless of whether ASM/ht^2 or ASM/wt was used. These findings support the recommendation that older people, especially older Asian men who have relatively small muscle mass, should engage in exercise programs to increase muscle mass and muscle strength. Further studies with large sample sizes are needed to assess whether sarcopenia increases the mortality risk in older women.

Supplementary Material

Supplementary material can be found at: http://biomedgerontology.oxfordjournals.org/

Funding

This study was supported by the National Research Foundation grant funded by the Korean government (Ministry of Education, Science and Technology; 2006-2005410), the grant from Seoul National University Bundang Hospital (02-2011-015; 11-2008-029), and grant (04-2011-0710) from the SNUH Research Fund.

Conflict of Interest

None declared

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