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Sarcopenia, Cardiopulmonary Fitness, and Physical Disability in Community-Dwelling Elderly People

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Background. *Sarcopenia* refers to the loss of skeletal muscle mass with aging. It is believed to be associated with functional impairment and physical disability.

Objective. The purposes of this study were: (1) to compare the physical activity, muscle strength (force-generating capacity), cardiopulmonary fitness, and physical disability in community-dwelling elderly people with sarcopenia, borderline sarcopenia, and normal skeletal muscle mass in Taiwan and (2) to test the hypothesis that sarcopenia is associated with physical disability and examine whether the association is mediated by decreased muscle strength or cardiopulmonary fitness.

Design. This was a cross-sectional investigation.

Methods. Two hundred seventy-five community-dwelling elderly people (148 men, 127 women) aged ≥65 years participated in the study. The participants were recruited from communities in the district of Zhongzheng, Taipei. Predicted skeletal muscle mass was estimated using a bioelectrical impedance analysis equation. The skeletal muscle mass index (SMI) was calculated by dividing skeletal muscle mass by height squared. Physical disability was assessed using the Groningen Activity Restriction Scale. Physical activity was assessed using a 7-day recall physical activity questionnaire. Cardiopulmonary fitness was assessed using a 3-minute step test, and grip strength was measured to represent muscle strength.

Results. Cardiopulmonary fitness was significantly lower in elderly people with sarcopenia than in those with normal SMIs. Grip strength and daily energy expenditure (kcal/kg/day) were not significantly different between the participants with sarcopenia and those with normal SMIs. The odds ratio for physical disability between the participants with sarcopenia and those with normal SMIs was 3.03 (95% confidence interval=1.21–7.61). The odds ratio decreased and the significant difference diminished after controlling for cardiopulmonary fitness.

Limitations. A causal relationship between sarcopenia and physical activity, cardiopulmonary fitness, and physical disability cannot be established because of the cross-sectional nature of study design.

Conclusions. Sarcopenia was associated with physical disability in elderly men. The association between sarcopenia and physical disability was mediated to a large extent by decreased cardiopulmonary fitness.

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The normal aging process is accompanied by declines in physical capacity,[1] mobility,[2] and endurance, which may result in the loss of independent living.[3] Muscle strength (force-generating capacity) and muscle mass play a significant role in the ability to maintain daily function, as well as the ability to participate in recreational activities.[4] *Sarcopenia* is the term coined by Rosenberg in identifying age-related decline in skeletal muscle mass and function.[5] Many factors are thought to contribute to sarcopenia,[6–8] including central nervous system decline, intrinsic loss of muscle contractile function, reduction in dietary protein, humoral effect of gonadal steroids, increase in catabolic stimuli, and decreased level of physical activity. The consequences of sarcopenia include decreases in muscle strength,[9] metabolic rate,[10] and maximal oxygen consumption ($\dot{V}O_2max$).[4,7] These physiologic decrements in maximal strength and cardiopulmonary fitness probably contribute to weakness and a loss of independence in daily living function.[11]

The cardiopulmonary system has received the most attention, as it is involved with the most basic functions of everyday life.[12] Maximal aerobic capacity has been demonstrated to decrease at the rate of approximately 1% per year after senescence.[13] This decline is due to decreased maximal cardiac output, muscle mass,[14] and oxidative capacity of skeletal muscle.[15] Cardiopulmonary fitness is related to the ability to perform large-muscle, dynamic, moderate- to high-intensity exercise for a certain time period.[16] However, few investigations of cardiopulmonary fitness in elderly people with sarcopenia have been reported in the literature.

In the frailty-related literature, it has been demonstrated that a loss of 30% of reserve capacity limits normal function, whereas a decrease of 70% may result in failure of most organ systems.[17] Some epidemiological studies have related sarcopenia to the onset of fragility and disability in elderly people.[18–21] *Physical disability* is defined as difficulty or dependency in carrying out activities necessary for independent living, including roles, tasks needed for self-care and household chores, and other activities important for a person's quality of life.[22] The New Mexico Elder Health Survey was the first large-scale epidemiologic study to report the relationship between sarcopenia and several measures of physical disability.[18] Janssen et al[20] reported that severe sarcopenia was independently associated with an increased likelihood of functional impairment and physical disability in older adults from the Third National Health and Nutrition Examination Survey (NHANES III). However, some epidemiological studies failed to observe any association between skeletal muscle mass and disability in elderly people.[23–25] Rolland et al[23] showed that low calf circumference, but not sarcopenia, was associated with self-reported physical disability in the European Patient Information and Documentation Systems (EPIDOS) Study. Thus, the relationship of sarcopenia to physical disability has yet to be fully examined.

As in the other developed countries, the proportion of elderly people in Taiwan has been increasing and now comprises more than 10% of the total population.[26] Our previous study[27] showed that the prevalence of sarcopenia in Taiwan (18.6% and 23.6% in women and men, respectively) is comparable to reported prevalence in Western countries. An important theoretical model of the pathway to late-life dependence proposed by Nagi in 1965 explains how active pathology evolves into physical impairment (eg, diminished cardiopulmonary fitness), functional limitations, and finally into disability (eg, dependence in activities of daily living [ADL]).[28,29] Although sarcopenia is reportedly associated with physical disability, impairment measures (eg, muscle strength, cardiopulmonary fitness) of the association between sarcopenia and physical disability have not received detailed examination. Therefore, the aims of this cross-sectional study were: (1) to compare the physical activity, muscle strength, cardiopulmonary fitness, and self-reported physical disability of community-dwelling elderly people with sarcopenia, borderline sarcopenia, and normal skeletal muscle mass in Taiwan and (2) to test the hypothesis that sarcopenia is associated with physical disability and examine whether the association is mediated by decreased muscle strength or cardiopulmonary fitness.

Method

Participants

We strategically placed posters in and recruited volunteers from communities in the district of Zhongzheng, Taipei. We contacted a total of 401 community-dwelling elderly people (≥65 years of age), of whom 126 (31.4%) did not respond (32 refused to participate, 73 did not live in the communities, and 21 were found to be ineligible). Volunteers were ineligible to participate if they had hyperthyroidism or hypothyroidism, were taking prescribed medications (eg, growth hormone, testosterone, progesterone) known to alter body composition,[30,31] had an amputation, were nonambulatory even with the use of a walker or a cane, or could not complete the questionnaire and measurements due to blindness or deafness. The respondents were invited for an interview and physical assessments. The data were collected by trained physical therapists following standard protocols. All participants gave informed consent before participation.

Each participant was interviewed using a structured questionnaire designed to elicit basic information (age, sex, and educational level) and information on medical conditions necessitating long-term treatment (eg, diabetes, hypertension, myocardial infarction, coronary heart disease, congestive heart failure, chronic bronchitis, emphysema, arthritis) and use of medications to treat these illnesses. Major chronic diseases were grouped into cardiovascular diseases (eg, coronary heart disease, hypertension, diabetes, hyperlipidemia), pulmonary diseases, gastrointestinal system diseases, orthopedic diseases, cancer, and "others." The assessments included resting vital signs, anthropometric measures, physical activity levels, grip strength and cardiopulmonary fitness, and self-reported physical disability.

Vital Signs and Anthropometric Measurements

All participants rested for about 5 minutes before heart rate and blood pressure measurements were taken. Blood pressure was measured using a sphygmomanometer, and the resting heart rate was measured by palpating the radial artery at the wrist for 1 minute. Body mass was measured to the nearest 0.1 kg, with the participants dressed in light clothing. Barefoot standing height was measured to the nearest 0.1 cm with a wall-mounted stadiometer.[32] Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). Body mass index was categorized according to the Bureau of Health Promotion standards in Taiwan: $<$18.5 kg/m^2=underweight, 18.5 to 23.9 kg/m^2=normal weight, 24.0 to 26.9 kg/m^2=overweight, and 27 kg/m^2=obesity. Circumferences of the waist and hip were obtained to the nearest 0.1 cm using a flexible plastic tape. Waist-hip ratio (WHR) was calculated as waist circumference divided by hip circumference.

Muscle strength. Grip strength of the dominant hand was measured in this study to represent general muscle strength, as it has been shown in previous studies to have a moderate to high correlation to the strength of large muscle groups.[33,34] It was measured with the elbow extended in the standing position using a Jamar handheld dynamometer.[*,35] Participants were asked to squeeze the dynamometer as hard as possible with one hand, and verbal encouragement was given during the test. Three successive measurements were taken, and the time between trials was about 15 seconds.[36] The best score of 3 trials was recorded for analysis. The reliability of grip strength measured with the Jamar dynamometer was reported to be .94 in community-dwelling elderly people.[37]

Body composition. Body composition was measured by means of a bioelectrical impedance analysis (BIA) technique using a Maltron body fat analyzer (Maltron BioScan 920[†]) with an operating frequency of 50 kHz at 800 μA. The participants lay supine on a nonconducting surface with their arms abducted from the trunk and legs slightly separated for 5 minutes. Four electrodes and cables were attached to the right hand and ankle, as shown in the user's manual. When the measurements stabilized, the analyzer displayed bioelectrical impedance directly and immediately through the calculation of the software. According to the strong relationships among measured impedance, fat-free mass (FFM), and total body water, many prediction equations were devel-

* Preston Corporation, PO Box 89, Jackson, MI 04204.

† Maltron International Ltd, PO Box 15, Rayleigh, Essex, United Kingdom SS6 9SN.

The Bottom Line

What do we already know about this topic?

Sarcopenia is the term used to describe age-related decline in skeletal muscle mass and function. Many epidemiological studies have linked sarcopenia to the onset of fragility and disability in elderly people.

What new information does this study offer?

Sarcopenia was associated with physical disability in elderly men in Taiwan. To a large extent, the association between sarcopenia and physical disability depended on the level of cardiopulmonary fitness.

If you're a patient, what might these findings mean for you?

Maintaining good cardiopulmonary fitness may help reduce long-term physical disability for elderly people with sarcopenia.

oped to estimate percentage of body fat and FFM.[38,39] These 2 types of data, the percentage of body fat and FFM, also could be directly displayed after BIA measurement. Previous studies have demonstrated excellent test-retest reliability for BIA-obtained measurements, with correlation coefficients ranging from .96 to .99 for resistance measurements.[39,40] Hydrostatic weighing and BIA-predicted correlation coefficients range from .71 to .93, with standard errors of estimate ranging from 2.7% to 4.7% body fat.[39,41]

Measurement of Skeletal Muscle Mass

Skeletal muscle mass was calculated using the BIA equation developed by Janssen et al[42]: skeletal muscle mass (in kilograms)=[0.401 × (height^2/resistance) + (3.825 × sex) − (0.071 × age)] + 5.102, where height is in centimeters; resistance is in ohms; for sex, men=1 and women=0; and age is in years. This BIA equation was validated through a comparison of the results of magnetic resonance imaging (MRI) assessment of whole body muscle mass in a sample of 41 adults varying in age and BMI.[27] The correlation between muscle mass predicted using BIA and muscle mass measured using MRI was .95, and the standard error of the estimate for predicting skeletal muscle mass from BIA was 7%.[27]

Skeletal muscle mass index. Absolute skeletal muscle mass was converted to a skeletal muscle mass index (SMI) by dividing by height squared (kg/m^2). The SMI was used for adjustment for stature and the mass of nonskeletal muscle tissues. This index was used in several epidemiological studies.[18–21]

Definition and classification of sarcopenia. According to the definition by Baumgartner et al,[18] sarcopenia was defined in this study as an SMI of 2 standard deviations or more below the normal sex-specific means for people 18 to 40 years of age. Participants were considered to have a normal SMI if the SMI was more than −1 standard deviation above the mean value for young adults who are healthy. *Borderline sarcopenia* was defined as an SMI within −1 to −2 standard deviations of the mean value for young adults who are healthy. In our previous work, the mean (±SD) of SMIs for men and women were 10.87±1.00 kg/m^2 and 7.88±0.73 kg/m^2, respectively.[27]

Physical Activity

Physical activity was evaluated with an interviewer-administered 7-day recall physical activity questionnaire, which was designed by Sallis et al in the Five-City Project.[43] This questionnaire provides calories expended on all activities during the previous 7-day period. The questionnaire includes information on occupational work and leisure activities. Duration of very strenuous activities (at least 7 metabolic equivalents [METs]), strenuous activities (5.1–6.9 METs), moderate activities (3–5 METs), and sleep time were self-reported within a half hour. Energy expenditure was the average of energy consumption for all measured activities. The total kilocalories per kilogram per day was the sum of energy consumed by all activities. In cases of impaired cognition (Mini-Mental State Examination score below 24), the evaluators obtained confirmation of the individual's physical activity levels from family members. The intraclass correlation coefficient for test-retest reliability for the 7-day recall physical activity questionnaire in 60- to 80-year-old men was .89.[44] The total energy expenditure was significantly correlated with average activity counts per minute as measured with triaxial accelerometers (r=.49).[44]

Cardiopulmonary Fitness

A 3-minute step test with a stool height of 30.5 cm (12 in) was performed with electrocardiographic (ECG) monitoring throughout the test period according to the *YMCA Fitness Testing and Assessment Manual*.[45] The alternating stepping cadence was modified and set at 80 bpm (4 clicks=one step cycle) for a stepping rate of 20 steps per minute for elderly people. The test was stopped immediately if a participant lost balance, missed the rhythm of stepping for three steps, or felt any discomfort in any stage of the test. If a participant could not complete the stepping test, the time when the test was terminated was recorded and used in the analysis. The results of the stepping test for participants who were taking medications affecting heart rate (eg, β-blockers, calcium channel blockers) were excluded. The fitness index was calculated using the following equation developed by Brouha et al[46]: fitness index=duration of exercise in seconds × 100/(sum of pulse counts during the recovery period) × 2. The sum of pulse counts obtained from the ECG recording 1 to 1.5, 2 to 2.5, and 3 to 3.5 minutes after stopping the test was used to determine the pulse rate. The correlation of fitness index to $\dot{V}O_2$max has been reported as 0.5 in Taiwanese adults who were healthy.[47]

Physical Disability

The Groningen Activity Restriction Scale (GARS) was used to assess physical disability. The GARS is a one-dimensional, hierarchical scale used to grade difficulties a person may experience when carrying out ADL tasks without help.[48,49] The GARS is a questionnaire with 18 items that assess daily activities on the basis of 1 of 4 response options (1 indicating complete independence, 4 indicating total lack of independence). The total score is a measure of a person's ability to take care of himself or herself and perform household activities. *Physical disability* was defined as any difficulty in performing one or more activities (total score≥19) in this study. Comparisons between the GARS and the 20-Item Short-Form Health Survey (SF-20) questionnaire subscale for physical functioning has yielded a strong correlation (r=−.72), supporting concurrent validity.[49]

Data Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS for Windows, release 13.0).[‡] Descriptive statistics are reported as mean ± standard deviations. A one-way analysis of variance and chi-square statistics were used to examine differences in the basic characteristics among the 3 groups. Pearson correlation coefficients were used to examine the bivariate relationships for sarcopenia and physical disability with anthropometric variables, physical activity, grip strength, and cardiopulmonary fitness. Multiple logistic regression analysis was used to determine the odds ratios (ORs) of physical disability when comparing the sarcopenia and borderline sarcopenia groups with the normal SMI group. Normal SMI was used as the reference category (OR=1.0). We used an extended-model approach for covariates adjustment: model 1=basic characteristics (age, BMI categories, and comorbidities [eg, cardiovascular diseases, pulmonary diseases, gastrointestinal system diseases, orthopedic diseases, cancer]); model 2=basic characteristics and physical activity; model 3=basic characteristics and grip strength; model 4=basic characteristics and fitness index; model 5=basic characteristics, physical activity, and grip strength; model 6=basic characteristics, physical activity, and fitness index; and model 7=basic characteristics, physical activity, grip strength, and fitness index. Age was included in the models as a continuous variable. Comorbidities were coded as 0 for absent and 1 for present. P values below .05 were considered statistically significant.

‡ SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

Role of the Funding Source

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Results

Basic Characteristics

Two hundred seventy-five volunteers (148 men, 127 women) completed the physical assessments. Sarcopenia was identified in 33 men (22.3%) and 28 women (22.0%), and borderline sarcopenia was identified in 47 men (31.8%) and 41 women (32.3%). Sixty-eight men (45.9%) and 58 women (45.7%) had normal SMIs. Participants' sex and sarcopenia status are shown in Table 1. Body weight, BMI, waist and hip circumference, and FFM were lower in the sarcopenia group than in the normal SMI group (P<.05) for both men and women. Concerning chronic comorbidities, orthopedic diseases were significantly higher in the normal SMI group for both men and women (P<.05).

Physical Activity, Cardiopulmonary Fitness, and Physical Disability

Daily total energy expenditure (kcal/day) and fitness index were significantly lower in the sarcopenia group than in the normal SMI group for both sexes (P<.05, Tab. 2). However, grip strength and daily energy expenditure (expressed as kilocalories per body weight in kilograms per day) were not significantly different between the sarcopenia and normal SMI groups for both sexes. In addition, the level of physical disability was significantly higher in men with sarcopenia than in men in the normal SMI (21.9±5.5 and 19.2±2.4, respectively, P<.05). Most women (78.7%) were totally independent in their activities of daily life. There was no significant difference in grip strength, fitness index, and GARS score between the borderline sarcopenia and normal SMI groups.

For the 3-minute step test, 8 men (1 in the sarcopenia group, 2 in the borderline sarcopenia group, and 5 in the normal SMI group) and 3 women (1 in the borderline sarcopenia group and 2 in the normal SMI group) took β-blockers or calcium channel blockers, which can affect heart rate, and thus were excluded from the calculation for fitness index.

Associations of Sarcopenia and Physical Disability and the Measured Parameters

Several measured parameters correlated significantly with SMI (sarcopenia) and GARS scores (physical disability) in men and women (Tab. 3). Body mass index and energy expenditures of physical activity correlated highly with sarcopenia and physical disability in both sexes (P<.05). Cardiopulmonary fitness index correlated significantly with SMI in both sexes, and it also correlated significantly with physical disability in men. In addition, a significant correlation between grip strength and SMI was found in men.

Sarcopenia and Physical Disability

Sarcopenia was associated with physical disability in men after controlling for basic characteristics. The OR for physical disability when comparing participants with sarcopenia with those with normal SMI was 3.03 (95% confidence interval [CI]=1.21–7.61) (Tab. 4). Physical activity, grip strength, and fitness index were subsequently introduced as covariates from model 2 to model 4. The ORs decreased and the statis-

Table 1.
Characteristics of the Participants

Variable	Men			Women		
	Sarcopenia (n=33)	Borderline Sarcopenia (n=47)	Normal SMI[a] (n=68)	Sarcopenia (n=28)	Borderline Sarcopenia (n=41)	Normal SMI (n=58)
Age (y)[b]	77.5±7.2	77.2±6.6	77.7±6.9	75.8±5.7	73.9±5.2	73.6±5.4
Skeletal muscle mass (kg)[b]	21.33±2.97	25.87±2.70[c]	28.72±2.91[c,d]	14.25±1.42	15.77±1.04[c]	18.56±2.10[c,d]
Skeletal muscle mass index (kg/m^2)[b]	8.23±0.71	9.32±0.28[c]	10.80±0.88[c,d]	6.07±0.27	6.72±0.39[c]	7.98±0.68[c,d]
Years of education[b]	6.0±4.8	6.3±5.1	6.5±4.8	6.1±4.6	6.9±4.9	6.0±5.0
Resting vital signs[b]						
Heart rate (bpm)	73.6±9.6	75.4±11.6	75.3±12.7	71.8±10.0	74.0±11.0	74.7±8.7
Systolic blood pressure (mm Hg)	124.2±18.7	129.4±16.0	130.5±16.7	129.1±15.1	131.2±17.9	132.1±16.3
Diastolic blood pressure (mm Hg)	68.5±10.6	73.6±10.0	70.9±11.8	71.5±9.6	74.1±8.9	72.6±10.2
Anthropometry[b]						
Body height (cm)	160.6±6.8	166.4±8.3	163.0±6.5	153.0±6.5	153.1±4.5	152.4±5.5
Body weight (kg)	59.2±9.0	65.9±10.4[c]	68.7±8.5[c]	49.5±6.3	53.9±8.0	61.8±9.3[c,d]
Body mass index (kg/m^2)	22.47±2.69	23.75±2.85	25.85±2.73[c,d]	21.13±2.42	22.94±2.80	26.57±3.55[c,d]
Waist circumference (cm)	86.1±8.7	90.7±9.8	92.4±8.1[c]	81.3±9.5	87.8±10.5	91.2±9.9[c]
Hip circumference (cm)	94.7±5.8	97.7±7.2	99.7±6.1[c]	91.9±5.8	95.9±7.5	100.2±7.4[c,d]
Waist-hip ratio	0.91±0.06	0.93±0.07	0.93±0.05	0.88±0.07	0.92±0.07	0.91±0.07
Fat (%)	26.4±6.7	27.4±9.2	24.8±6.0	32.6±10.0	33.6±9.2	36.7±8.3
Fat-free mass (kg)	42.52±6.10	47.18±5.56[c]	51.41±5.56[c,d]	33.06±4.98	35.46±5.93	38.68±5.21[c,d]
Morbidity[e]						
Cardiovascular risk diseases	14 (42%)	24 (54%)	43 (63%)	11 (38%)	19 (46%)	35 (60%)
Pulmonary diseases	5 (15%)	2 (5%)	6 (9%)	0 (0%)	0 (0%)	1 (2%)
Gastrointestinal diseases	1 (4%)	6 (14%)	1 (2%)	0 (0%)	2 (4%)	2 (4%)
Orthopedic diseases	4 (12%)	6 (14%)	18 (26%)[c,d]	8 (30%)	7 (18%)	27 (47%)[d]
Cancer	3 (8%)	2 (5%)	1 (2%)	3 (10%)	0 (0%)	0 (0%)
Others	4 (12%)	4 (10%)	24 (30%)	4 (14%)	5 (11%)	4 (6%)

[a] SMI=skeletal muscle mass index.
[b] Data are expressed as mean±SD.
[c] Significantly different from the sarcopenia group within the same sex, $P<.017$.
[d] Significantly different from the borderline sarcopenia group within the same sex, $P<.017$.
[e] Data are expressed as numbers of participants (% of subgroup numbers).

tical significance diminished after controlling for fitness index, which suggested that the association between sarcopenia and physical disability could be partially explained by fitness index. However, sarcopenia remained significantly correlated with physical disability (OR=3.03, 95% CI=1.20–7.62) after adjustment for grip strength and physical activity. We did not observe any association between sarcopenia and physical disability in women or between borderline sarcopenia and physical disability in either sex.

Discussion

Few studies of sarcopenia have been carried out in Asia, although the proportion of elderly people in the population is similar in Asia and in Western countries.[50] The present results showed that the participants with sarcopenia tended to have lower cardiopulmonary fitness and physical activity compared with those with normal SMI, regardless of sex. However, physical disability was more closely associated with sarcopenia than with a normal SMI in elderly community-dwelling men. Moreover, our results suggested that the association between sarcopenia and physical disability, to a large extent, could be explained by cardiopulmonary fitness.

Table 2.
Physical Activity, Grip Strength, Cardiopulmonary Fitness, and Physical Disability of the Participants

Variable	Men			Women		
	Sarcopenia (n=33)	Borderline Sarcopenia (n=47)	Normal SMI[a] (n=68)	Sarcopenia (n=28)	Borderline Sarcopenia (n=41)	Normal SMI (n=58)
Energy expenditure (kcal/d)[b]	2,129.3±332.3	2,159.1±291.8	2,414.5±316.2[c,d]	1,747.8±277.9	1,991.0±290.6[c]	2,251.3±352.6[c,d]
Energy expenditure (kcal/kg/d)[b]	35.22±2.96	34.24±4.72	36.92±5.13[d]	35.32±3.13	36.59±3.24	37.15±3.90
Grip strength (kg)[b]	23.3±9.0	25.6±8.5	27.7±8.1	13.5±5.5	17.0±5.3	17.3±6.7
Fitness index[b,e]	56.3±16.3	61.9±14.9	66.7±11.7	47.0±13.6	60.6±16.3[c]	66.3±15.2[c]
Physical disability (GARS[f] score)[b]	21.9±5.5	20.4±5.5	19.2±2.4[c]	18.4±1.2	18.3±0.9	18.6±1.9
GARS score ≥19 (n, %)[g]	19 (58%)	18 (38%)	23 (34%)	7 (25%)	8 (19%)	11 (19%)

[a] SMI=skeletal muscle mass index.
[b] Data are expressed as mean±SD.
[c] Significantly different from the sarcopenia group within the same sex, $P<.017$.
[d] Significantly different from the borderline sarcopenia group within the same sex, $P<.017$.
[e] Eight men (1 in sarcopenia group, 2 in borderline sarcopenia group, and 5 in normal SMI group) and 3 women (1 in borderline sarcopenia group and 2 in normal SMI group) took medicines affecting heart rate and were excluded from this part of the analysis.
[f] GARS=Groningen Activity Restriction Scale.
[g] Tested by chi-square test, and no significant difference was detected.

Sarcopenia and Physical Disability

Sarcopenia was independently associated with an increased likelihood of physical disability in older men, whereas borderline sarcopenia was not clearly associated with an increased likelihood of physical disability. Taken together, these results suggest that modest reductions in skeletal muscle mass with aging do not cause physical disability. However, if muscle mass continues to decrease to a critical point, there is an increasing likelihood that physical function will be compromised. Several studies have shown a relationship between sarcopenia and physical disability.[18–21] Baumgartner and coworkers[18] reported an association of sarcopenia with self-reported physical disability assessed by the instrumental activities of daily living (IADL) scale, use of a cane or walker, and a history of falling in non-Hispanic white and Mexican American elderly men and women. After adjustment for basic characteristics, such as age, obesity, smoking, and comorbidities, women with sarcopenia had a 3.6 times higher rate of disability, and men had a 4.1 times higher rate, compared with individuals with normal muscle mass.[18] Melton et al[51] reported an association of sarcopenia with difficulty in walking

Table 3.
Pearson Correlation Coefficients Between Sarcopenia and Physical Disability and the Measured Parameters

Variable	Skeletal Muscle Mass Index		Physical Disability[a]	
	Men	Women	Men	Women
Age (y)	−0.01	−0.05	0.14	0.06
Body mass index (kg/m²)	0.55[b]	0.60[b]	−0.20[c]	0.40[b]
Fat mass (kg)	−0.09	0.17	−0.03	0.32[b]
Waist circumference (cm)	0.32[b]	0.34[b]	−0.17	0.20[c]
Physical activity (kcal/d)	0.47[b]	0.51[b]	−0.18[c]	0.24[b]
Physical activity (kcal/kg/d)	0.06	0.02	−0.06	−0.17
Grip strength (kg)	0.19[c]	0.13	−0.13	−0.12
Fitness index	0.27[b]	0.36[b]	−0.35[b]	−0.11

[a] Physical disability was assessed by the Groningen Activity Restriction Scale.
[b] $P<.01$.
[c] $P<.05$.

Table 4.
Multiple Logistic Regression Models Testing the Association Between Sarcopenia and Physical Disability[a]

Model	Sarcopenia		Borderline Sarcopenia	
	Men OR (95% CI)	Women OR (95% CI)	Men OR (95% CI)	Women OR (95% CI)
Unadjusted	2.66 (1.13–6.24)[b]	2.45 (0.75–8.26)	1.21 (0.56–2.63)	1.46 (0.39–2.39)
Model 1	3.03 (1.21–7.61)[b]	1.60 (0.39–6.58)	1.36 (0.59–3.11)	1.25 (0.37–4.79)
Model 2	3.03 (1.21–7.56)[b]	2.18 (0.50–8.47)	1.20 (0.51–2.80)	1.54 (0.39–6.17)
Model 3	3.07 (1.21–7.77)[b]	2.23 (0.52–9.58)	1.36 (0.59–3.10)	1.82 (0.44–7.49)
Model 4	1.45 (0.45–4.66)	2.03 (0.43–9.66)	0.86 (0.30–2.46)	1.80 (0.33–9.81)
Model 5	3.03 (1.20–7.62)[b]	2.47 (0.56–10.96)	1.20 (0.51–2.81)	1.94 (0.47–8.13)
Model 6	1.50 (0.46–4.90)	2.43 (0.49–12.10)	0.80 (0.27–2.32)	2.22 (0.39–12.61)
Model 7	1.56 (0.47–5.18)	2.78 (0.53–14.53)	0.80 (0.27–2.33)	2.46 (0.43–14.12)

[a] Physical disability was defined as reporting any difficulty in one or more activities in the Groningen Activity Restriction Scale. Model 1=controlling for basic characteristics (age, body mass index categories, and comorbidities); model 2=controlling for basic characteristics and physical activity; model 3=controlling for basic characteristics and grip strength; model 4=controlling for basic characteristics and fitness index; model 5=controlling for basic characteristics, physical activity, and grip strength; model 6=controlling for basic characteristics, physical activity, and fitness index; and model 7=controlling for basic characteristics, physical activity, grip strength, and fitness index. Odds ratio (OR) indicates physical disability comparing participants with sarcopenia or borderline sarcopenia with those with normal skeletal muscle mass. CI=confidence interval.
[b] $P<.05$.

in older men and women. On the other hand, Janssen et al[20] reported that only severe sarcopenia was independently associated with an increased likelihood of functional impairment and physical disability in older adults after adjusting for potential confounding variables such as age, race, health behaviors, and comorbidity. A longitudinal study by Janssen[21] showed that the effect of sarcopenia on physical disability was considerably smaller. Rolland and coworkers[23] reported that sarcopenia was not correlated with IADL scale, physical difficulties, or risk of falling in ambulatory participants with no history of hip fracture or hip replacement. The disparities may be related to the differences in the outcome measures and the characteristics of the studied populations.

Our results showed that sarcopenia was significantly related to physical disability only in men. This finding is similar to those of previous studies. Janssen et al[20] reported that sarcopenia was a strong predictor of physical disability in men than women, and Zoico et al[25] found no relationship between sarcopenia indexes and disability in women who were healthy. For elderly women, Janssen et al[20] reported that very high SMI values and high body fat mass were associated with increased physical disability. Some studies have shown that sarcopenic obesity is more strongly associated with IADL disability than with either obesity or sarcopenia alone.[52,53] Iannuzzi-Sucich et al[54] recently suggested that the most important factor in determining physical disability in people who are relatively high functioning may be the proportion of body fat, whereas in frail individuals, it may be the level of lean mass that would be critically decisive. In the present study, 78.7% of elderly women were totally independent in their ADL tasks, and this low physical disability rate might conceal the relationship between sarcopenia and physical disability in elderly women.

Sarcopenia and Cardiopulmonary Fitness

It is well established that cardiopulmonary fitness and skeletal muscle mass progressively decline in the aged population, and both factors contribute to weakness and physical disability in elderly people.[8,11] A previous study[14] showed that a large portion of the age-associated decline in $\dot{V}O_2max$ is explained by the loss of skeletal muscle mass. The present study showed a significantly lower fitness index in elderly participants with sarcopenia than in those with a normal SMI, regardless of sex. In addition, our study has the advantage of analyzing outcomes beyond traditional measures of physical disability and elucidating the role of cardiopulmonary fitness in sarcopenia and physical disability. These findings suggest that improving cardiopulmonary fitness might be an important strategy to prevent physical disability in elderly people with sarcopenia.

Few studies have addressed the relationship between sarcopenia and cardiopulmonary fitness. One of the reasons might be the lack of suitable instruments for a large-scale investigation. Cardiopulmonary exercise testing is a well-established procedure that provides peak oxygen uptake as the gold standard in determining exercise capacity,[16] but it is poorly accessible for a large-scale, community-based investigation. Among the field tests, the 3-minute step test is an easy-to-administer, inexpensive, and safe test that provides a measure of submaximal cardiorespiratory or endurance fitness.[55] As several step tests with different step heights and different stepping rates have been developed to provide cardiopulmonary fitness tests,[56,57] the procedure and scoring equation for 3-minute step test used in this study specifically address cardiopulmonary fitness categorized as a test item in the National Physical Fitness Battery in Taiwan.[47,58,59] The fitness index on the basis of the heart rate recovery has been shown to be correlated (r=.5) with peak oxygen consumption in Taiwanese adults who were healthy.[47]

Sarcopenia and Physical Activity

Older men and women who are less physically active have less skeletal muscle mass, which would increase the prevalence of disability.[60] Longitudinal studies have documented that increased physical activity or strengthening exercise can reduce sarcopenia-related muscle weakness.[61,62] A vicious cycle of sarcopenia and physical inactivity has been proposed.[8] As regular physical activity decreases with age, there may be a down-regulation of physiological systems as they adapt to the reduced workload. As skeletal muscular and cardiovascular function decline, an increased perception of effort for a similar-intensity task will increase the likelihood of avoiding physical work. Physical activity will continue to decline and thus lead to more severe sarcopenia.

Although physical inactivity has been recognized as a significant factor contributing to age-related sarcopenia, only a few epidemiological studies have reported physical activity levels in elderly people with sarcopenia.[18,19,54] In addition, most of them graded physical activity levels by participants' reports of weekly frequency of engagement in various activities but not quantitative data measuring energy expenditure.[18,19] Baumgartner and colleagues[18] revealed physical activity to be a predictor of skeletal muscle mass in women. By contrast, Iannuzzi-Sucich et al[54] did not find a significant relationship between sarcopenia and physical activity (estimated by Physical Activity Scale for the Elderly score), possibly because volunteers who apparently were healthy and different physical assessment instruments were used. Our study examined the quantitative energy expenditure of elderly people with and without sarcopenia as assessed with the 7-day recall physical activity questionnaire and revealed no significant correlation between physical activity energy expenditure and sarcopenia. This finding concurred with the results of Iannuzzi-Sucich et al,[54] who also assessed physical activity using quantitative instruments. Therefore, from the research evidence so far, it is critical that future studies should investigate the relationship between sarcopenia and physical activity using quantitative instruments.

Limitations

Several limitations of the study must be acknowledged. First, this was a cross-sectional study of a moderate number of participants. On this basis, a causal relationship between sarcopenia and self-reported physical disability cannot be established. Second, the relatively low response rate (69%) to participation might raise the possibility that frail older individuals with more severe physical disability and sarcopenia were not included in this study, thereby producing a bias and an inability to fully address the relationship between the grip strength and physical disability. Finally, our participants were limited to community-dwelling elderly people. Thus, the relationship between sarcopenia and physical disability cannot be extrapolated to institutionalized elderly people or the entire elderly population in Taiwan.

Conclusion

This study indicated that sarcopenia was associated with physical disability in elderly men. The association between sarcopenia and physical disability, to a large extent, was mediated by cardiopulmonary fitness. Therefore, the findings underscore the need for prospective studies to explore a cardiopulmonary fitness-specific prevention or treatment regimen for elderly people with sarcopenia to reduce their physical disability in the long term.

All authors provided concept/idea/research design, writing, and data analysis. Dr Kuo provided data collection. Dr Wu provided facilities/equipment. Dr Kuo, and Dr Wu provided consultation (including review of manuscript before submission).

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