

Original Article

Age-related decline in skeletal muscle mass and function among elderly men and women in Shanghai, China: a cross sectional study

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Objective: To investigate the relationship of muscle mass and muscle function with age. **Methods and Study Design:** The study including 415 participants (aged 60-99 years). Upper (UMM) and lower (LMM) limbs muscle mass and whole body fat free mass (FFM) were measured by bioelectrical impedance analysis. The appendicular skeletal muscle mass (ASM) index (ASM/height²) was calculated. Muscle function was assessed by measuring hand grip strength (HGS) and gait speed. **Results:** Using ASM index cutoff values we found that higher prevalence of sarcopenia in women than in men (33.5% vs 23.6%, $p=0.025$). In the upper limb, HGS ($\beta=-0.809$) declined more rapidly with age than did UMM ($\beta=-0.592$) in men, but not in women ($\beta=-0.389$ and $\beta=-0.486$ respectively). In the lower limb, gait speed declined more rapidly than LMM in both men ($\beta=-0.683$ vs $\beta=-0.442$) and women ($\beta=-1.00$ vs $\beta=-0.461$). The variance of UMM explained 28-29% of the variance of HGS, and LMM explained 7-8% of the variance of gait speed in women and men respectively. In addition to the common predictors (BMI and age), the specific predictors were smoking, exercise and education for FFM and ASM, and smoking, drinking and exercise for HGS ($p<0.05$). **Conclusions:** Loss of muscle function is greater than the decline of muscle mass particularly in the upper limbs in men. However, women are more prone to have low muscle mass than the men. Exercise programs need to be designed gender specifically.

Key Words: sarcopenia, muscle mass, strength, physical performance, elderly

INTRODUCTION

Sarcopenia is characterized by an age-related decline of skeletal muscle plus low muscle strength and/or physical performance.^{1,2} Sarcopenia is a strong predictor of falls, physical disability, morbidity and mortality.^{3,4} Sarcopenia is also associated with increased risks of heart disease, hypertension and type II diabetes.^{5,6} The prevalence of sarcopenia in subjects over 60 years of age varies across studies from 8-40% depending on the definition of sarcopenia, the age range of the subjects, and the assessment tool used.⁷ Asian Consensus Report for Sarcopenia (2014, AWGS)¹ showed that in Hong Kong the prevalence of low muscle mass determined by dual X-ray absorptiometry (DXA) was 12.3% in men and 7.6% in women aged 70 years and older using ASM/height² thresholds of 5.72 kg/m², and 4.82 kg/m² respectively. In Beijing, the prevalence of low muscle mass was reported to be 53.2% in an elderly population over 80 years old using DXA.⁸

After the age of 30, muscle mass decreases by about 3-8% per decade. The rate of decline accelerates after the

age of 60.⁹ At the same time, muscle strength declines annually by approximately 1-1.5% between 50 and 60 years of age, and by approximately 3% annually thereafter.¹⁰ Previous studies have shown that muscle mass is associated with muscle strength.^{11,12} However, whether the loss of muscle mass is associated with the decline in strength in older adults, and whether muscle function (strength) declines more rapidly than the concomitant loss of muscle mass, are not clear. Earlier studies have shown that the age-dependent decline in strength is not explained by the loss of muscle mass alone.¹³ Whether the relation-

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ship between muscle mass and strength is gender specific is also unknown.

Given the fact that the population of individuals aged 60 years or older globally is increasing rapidly at a rate that is more than twice that of the total world population,¹⁴ and that the elderly population over the age of 60 will reach 200 million by the end of 2014 in China, the public health impact of sarcopenia is potentially enormous.

In this study, we aimed to investigate the relationship of muscle mass and muscle function with age and gender in the elderly men and women resident in Shanghai, China. The results may be useful for developing gender specific intervention programs to reduce the risk of sarcopenia.

SUBJECTS AND METHODS

Subjects

The study subjects consisted of 212 men and 202 women ($60 \leq \text{age} < 100$ years, mean age 72.4 ± 8.0 years) who were recruited through printed advertisement or by word of mouth between July 2013 and April 2014 from the health survey center of Shanghai Huadong Hospital, affiliated with Fudan University. The inclusion criteria were: (1) subjects who had been living in Shanghai for five years or more; (2) subjects aged 60 years or older; (3) participants understood verbal instructions and were able to walk for 4 m. Each subject was interviewed using a structured questionnaire to assess demographic characteristics and lifestyle factors. Smoking status was categorized as either current smoker or nonsmoker. Alcohol drinking was defined as consumption of one or more drinks per day. Education level was categorized as less than high school level vs high school level and above. Regular exercise was defined as exercise on a regular basis for more than 30 minutes at a time and more than three times per week. The main types of physical activities were recorded, and included walking, gymnastics, cycling, and use of exercise equipment. All measurements were performed by trained research dietitians. The study was approved by the Human Ethics Committee for Human Experiments of Fudan University Affiliated Hua Dong Hospital, China. According to the Declaration of Helsinki, all participants provided signed informed consent prior to the assessments.

Body composition

Weight, fat free mass (FFM) and appendicular skeletal muscle mass were assessed using a bioelectrical impedance analysis (BIA) device (Biaspace Inbody 720, Korea). A tetra polar eight-point tactile electrode system was used according to the manufacturer's instructions which separately measured impedance of the subject's trunk, upper limb and lower limb at six different frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz and 1 M kHz) for each of the body segments. Upper limb and lower limb muscle mass (UMM and LMM respectively) were determined, and appendicular muscle mass (ASM) was calculated as the sum of UMM and LMM. Muscle mass index was calculated as $\text{ASM}/\text{height}^2$.¹⁵ Wrist circumference and height were measured with a measuring tape according to standardized procedures. The body mass index (BMI) for each

participant was calculated by dividing body weight by height squared (kg/m^2).¹⁶ According to AWGS suggestions,¹ cutoff values of muscle mass index was $7.0 \text{ kg}/\text{m}^2$ for men and $5.7 \text{ kg}/\text{m}^2$ for women to identify low muscle mass.

Muscle function

HGS (in kg) was measured using an electronic hand dynamometer (CAMRY EH101, GD, China). Trained research dietitians administered the test and recorded the results of three measurements for the dominant hand. The maximum value was used in the analysis.¹² Gait performance was measured by recording the time required to walk 4 m under normal conditions and at the subjects' usual pace. To assess walking speed, subjects were instructed to stand with both feet touching the starting line and to begin walking after a verbal command. The time was recorded when participants finished crossing the distance between the first and the second line.¹⁷ Low hand-grip strength was defined as $<26 \text{ kg}$ for men and $<18 \text{ kg}$ for women, again according to AWGS suggestions.¹ According to EWGSOP (The European Working Group on Sarcopenia in Older People) proposal, a cutoff value of $0.8 \text{ m}/\text{s}$ was used to identify sarcopenia by gait speed (4 m).²

Statistical analysis

In the present study, SPSS version 20.0 was used for the statistical analyses. Means and standard deviations were calculated for continuous data. Categorical variables were expressed by number or percentage. The two-sample *t*-test was used for comparing continuous variables of study participants' characteristics by gender; the Chi-square test was used for categorical variables. Linear regression analysis was used to assess the associations between muscle mass and muscle performance, and was used to assess the change of muscle mass and muscle function with age. To compare the decline of muscle mass and muscle function with age and plot them on the same scale, the variables were normalized by expressing them as a percentage of the maximum value in each case. To determine what factors were associated with UMM, LMM, ASM, FFM, HGS and gait speed, we used the generalized linear models. The independent variables were UMM, LMM, ASM, FFM, HGS and gait speed, and the predictors included in the model were age, BMI, smoking, drinking, exercise, and education. All statistical tests were two-tailed, and $p < 0.05$ was considered significant.

RESULTS

Comparison of characteristics of the study participants by gender

The characteristics of the study participants were shown in Table 1. Age, waist circumference and BMI were similar between the elderly men and women ($p > 0.05$). Walking speed also did not differ between men and women ($p = 0.156$). The height and weight of women was lower than that of the men ($p < 0.001$). The men had higher values of HGS, UMM, LMM, ASM, $\text{ASM}/\text{height}^2$ and FFM than the women ($p < 0.001$).

In women, the proportion of subjects below the cutoff value using $\text{ASM}/\text{height}^2$ was significantly higher than in

Table 1. Characteristics of study participants

	Total (n=415)	Men (n=212)	Women (n=203)	<i>p</i> value	
Age (years)	72.4±8.0	73.1±8.6	71.8±7.3	0.536	
Height (cm)**	161±8.6	168±6.2	155±6.1	<0.001	
Weight (kg)**	63.0±11.0	68.2±9.5	57.6±9.8	<0.001	
BMI (kg/m ²)	24.0±3.1	24.2±2.8	23.8±3.4	0.111	
Waist circumference (cm)	89.5±9.3	90.3±8.7	88.7±9.9	0.086	
UMM (kg)**	4.6±1.3	5.5±1.0	3.6±0.8	<0.001	
LMM (kg)**	13.3±3.1	15.5±2.1	10.9±1.9	<0.001	
ASM (kg)**	17.9±4.2	21.0±3.0	14.6±2.5	<0.001	
ASM/height ² (kg/m ²)**	6.7±1.0	7.4±0.7	6.0±0.7	<0.001	
FFM (kg)	43.7±8.3	49.8±6.0	37.3±4.8	<0.001	
HGS (kg)**	31.5±8.2	36.1±8.0	26.7±5.1	<0.001	
Gait speed (m/s)*	0.96±0.24	0.98±0.26	0.95±0.22	0.156	
		N (%)		χ^2	<i>p</i> value
Low muscle mass*	118 (28.4)	50 (23.6)	68 (33.5)	5.01	0.025
Low HGS	26 (6.3)	15 (7.1)	11 (5.4)	0.49	0.547
Low gait speed*	81 (19.5)	38 (17.9)	43 (20.2)	0.70	0.458
high school level and above**	345 (83.1)	187 (87.8)	158 (78.2)	7.96	0.005
Smoking**	42 (10.1)	40 (18.8)	2 (1)	36.5	<0.001
Alcohol**	23 (5.5)	22 (10.4)	1 (0.5)	19.4	<0.001
Regular exercise	243 (58.6)	130 (61.3)	113 (55.7)	1.367	0.273

ASM: appendicular skeletal muscle mass; HGS: handgrip strength; FFM: fat free mass; BMI: body mass index; UMM: upper limbs skeletal muscle mass; LMM: lower limbs skeletal muscle mass.

Values are presented as mean±SD or number (%).

**p*<0.05, male vs female participants by two-sample t test or the Chi-square test

***p*<0.01, male vs female participants by two-sample t test or the Chi-square test

men (33.5% vs 23.6%, $\chi^2=5.01$, *p*=0.025). Using HGS and gait speed, the percentage of subjects below the cut-off values did not differ between the two genders ($\chi^2=0.49$, *p*=0.547; vs $\chi^2=0.70$, *p*=0.458).

Compared to women, the men were more likely to smoke and drink (*p*<0.001). The percentage of subjects with a higher education was greater in men than in women (*p*=0.005). The main types of regular sports activities were walking (60%), gymnastics (16%), cycling (7%), use of exercise equipment (4%) and others (15.2%). There were no differences in duration and type of exercise between men and women.

Changes of skeletal muscle mass and muscle function with age

In the upper limb, HGS ($\beta=-0.809$) declined more rapidly with age than did UMM ($\beta=-0.592$) in men, but not in women ($\beta=-0.389$ and $\beta=-0.486$ respectively). In the lower limb, gait speed declined more rapidly than LMM in both men ($\beta=-0.683$ vs $\beta=-0.442$) and women ($\beta=-1.00$ vs $\beta=-0.461$). (Figure 1)

Associations between muscle mass and muscle function and predictors

We further performed linear regression analysis to assess the associations between muscle mass and muscle performance. As shown in Figure 2, HGS correlated significantly with UMM (men $R^2=0.282$ and women $R^2=0.286$, *p*<0.05). Gait speed correlated with LMM (men $R^2=0.080$ and women $R^2=0.066$, *p*<0.05). The common predictors were BMI and age for UMM, LMM, ASM, FFM and HGS in both men and women (Table 2). The specific additional predictors were smoking, exercise, and education for FFM and ASM in men, and were smoking, drinking, education and exercise in men and exercise in women for

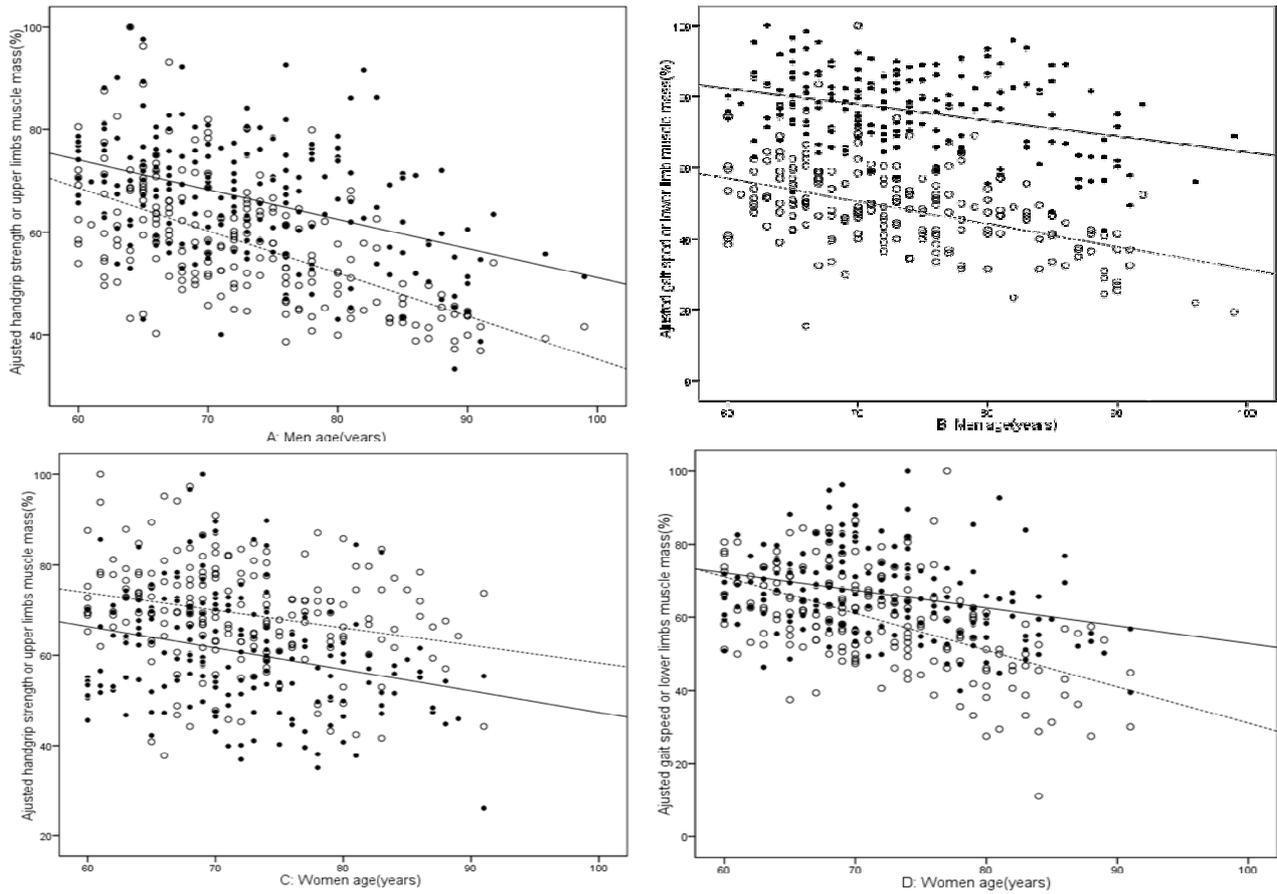
HGS, respectively.

DISCUSSION

The present study evaluated the relationship of muscle mass and muscle function (strength and performance) with aging by gender in elderly Shanghai Chinese. Our results were in agreement with earlier studies indicating loss of skeletal muscle mass and strength and declining physical performance with aging.^{1,2} However, our results further indicated that the loss of skeletal muscle mass and strength and low physical performance differed between genders: grip strength declined more rapidly than the concomitant loss of upper limbs muscle mass in men, but opposite was true in women. Also gait speed declined more rapidly than the loss of lower limb muscle mass in both men and women with age.

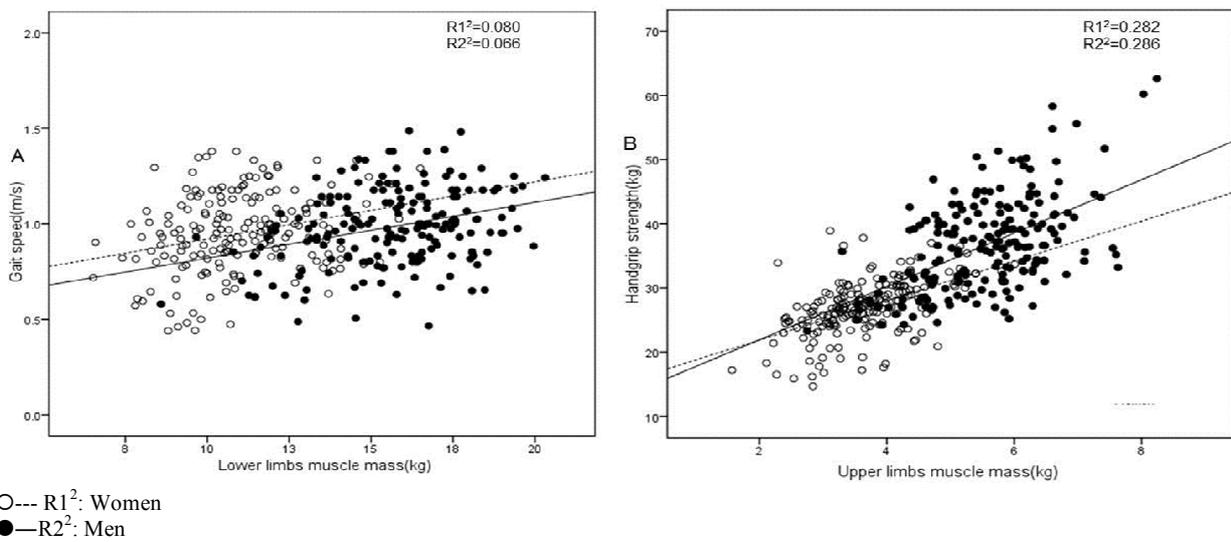
Loss of skeletal muscle mass is a characteristic manifestation of aging. The proportion of low muscle mass in our study was 23.6% in elderly men and 33.5% in women which was higher than that in Japan (men 11.3% and women 10.7%) and Korea (men 21.8% and women 22.1%). Our study used cutoff values of ASM/height² <7.0 kg/m² for men and <5.7 kg/m² for women according to AWGS suggestions¹ while the Japanese used cutoff values of 7.0 kg/m² and <5.8 kg/m², and the Koreans used <6.75 kg/m² and <5.07 kg/m² for men and women respectively. In addition, in China, subjects aged 60 years and older are defined as elderly but in Japan and Korea the definition is >65 years.¹ The different cutoff values for low muscle mass and age definition for elderly subjects may partly explain the observed high proportion of low muscle mass in China compared to Japan and Korea.

Muscle mass and strength are interrelated (i.e., larger-sized muscle brings greater force). Omid et al found a strong correlation between BIA-estimated skeletal muscle



○---: Handgrip strength/gait speed
 ●—: Upper/lower muscle mass
 A: handgrip strength $\beta = -0.809$ vs upper limbs muscle mass $\beta = -0.592$
 B: gait speed $\beta = -0.683$ vs lower limbs muscle mass $\beta = -0.442$
 C: handgrip strength $\beta = -0.389$ vs upper limbs muscle mass $\beta = -0.486$
 D: gait speed $\beta = -1.00$ vs lower limbs muscle mass $\beta = -0.461$

Figure 1. The decline of adjusted hand grip strength and adjusted upper limbs muscle mass in men (A) and women (B) with age. The decline of adjusted gait speed and adjusted lower limbs muscle mass in men (C) and women (D).



○--- R1²: Women
 ●— R2²: Men

Figure 2. The relationships between lower limbs muscle mass and gait speed (A), and upper limbs muscle mass and hand grip strength (B) by gender.

Table 2. Generalized linear models predicting muscle mass variables, grip strength and gait speed

Dependent variable	Predictors	Men		Women	
		β	Main effect <i>p</i> -value	β	Main effect <i>p</i> -value
UMM	BMI	0.194	<0.001	0.150	<0.001
	Age	-0.634	0.002	-0.016	<0.001
LMM	BMI	0.129	<0.001	0.229	<0.001
	Age	-0.345	<0.001	-0.050	<0.001
ASM	Smoking	-0.392	0.031	0.592	0.409
	Exercise	0.479	<0.001	0.269	0.064
	BMI	0.445	<0.001	0.379	<0.001
	Education	1.08	<0.001	-0.804	0.430
	Age	-0.298	<0.001	-1.04	<0.001
FFM	Smoking	-0.438	0.016	0.319	0.656
	Exercise	1.197	<0.001	0.257	0.077
	BMI	1.06	<0.001	0.771	<0.001
	Education	2.11	<0.001	-1.61	0.113
	Age	-1.13	<0.001	-0.705	<0.001
HGS	Smoking	-1.47	<0.001	-3.31	0.563
	Drinking	-1.32	<0.001	-0.525	0.672
	Exercise	0.346	0.016	0.414	0.004
	BMI	0.546	<0.001	0.134	<0.001
	Education	-0.805	<0.001	0.342	0.734
	Age	-0.358	<0.001	-0.134	0.001

ASM: appendicular skeletal muscle mass; HGS: handgrip strength; FFM: fat free mass; BMI: body mass index; UMM: upper limbs skeletal muscle mass; LMM: lower limbs skeletal muscle mass.

The dependent variables included UMM, LMM, ASM, FFM, HGS and gait speed. Only the significant predictors in the model are shown in the table.

mass (upper extremity and torso) and upper extremity (shoulder) strength independent of gender.¹¹ A significant correlation between muscle mass and muscle strength was found both in over 80-year old men and women in the BELFRAIL study.¹² Some studies have also shown that maintaining or gaining muscle mass does not prevent an aging-associated decline in muscle strength,¹³ and that low muscle strength was a better indicator for physical performance than low muscle mass.¹⁵ We found that upper limbs muscle mass was associated with HGS, and lower limbs muscle mass with gait speed both in men and women. However, the decline of HGS was greater than that of upper limbs MM in men while the result was different which was not in agreement with early studies in women.¹³ This difference was not due to participation in exercise since men and women did not differ in regular exercise duration and type. The observed difference may be attributed to the phenomena that old women do more housework (i.e., hold babies, shopping, cooking, cleaning, etc.) than old men in general in China. However, we did not measure daily activity and thus cannot confirm this speculation.

Low physical activity and sedentary lifestyle are the main causes of sarcopenia.¹⁸ Although participating in exercise is good for our health in general, for the specific purpose of prevention certain dysfunction or disease it may be important to have a specific type of exercise. Resistance and aerobic exercise are important ways to prevent sarcopenia.¹⁹ Progressive resistance training can increase the cross-sectional area of muscle fibers and decrease frailty in very old persons.²⁰ Aerobic exercise, on the other hand, is mainly beneficial for cardiovascular function and the effect on muscle mass is limited.²¹ In our study, the most common exercise was walking which

accounted for about 60% of the participants' exercise. A previous study reported that Chinese elderly people took part in more aerobic exercise and less resistive exercise²² which, to some extent, supports our finding. Considering our observation that the decline of muscle mass and function is gender specific, our results suggest that elderly men may benefit most from exercise aimed at functional movement of upper limbs while for women exercise aimed at increasing muscle mass and functional movement of lower limbs may be better.

Although it is unknown that whether alcohol consumption is a direct cause of sarcopenia, studies suggest that chronic alcohol consumption may promote loss of muscle mass and strength in old age.¹⁸ Tobacco smoking is also a risk factor for sarcopenia.¹⁸ Castillo et al²³ have found that the people who were current smokers were more likely to have sarcopenia. The reason may be attributed to increased oxidative stress and activation of signaling pathways which trigger up-regulation of muscle-specific E3 ubiquitin ligases.¹⁸ Our results revealed that low muscle mass and muscle strength were associated with alcohol consumption and smoking in men, but not in women. The reason may be that compared to women, the men were more likely to smoke and drink. In our study, elderly men with a higher level of education tended to have higher ASM and FFM, but lower HGS. A possible explanation could be socio-economic: men with higher education status tend to be middle class rather than working class and may differ in terms of physical activity and diet.

This study had some limitations. Firstly, this is a cross-sectional study. Ideally longitudinal studies should be performed to validate our results. Secondly, we used 4-m walk test rather than the 6-m walk proposed by AWGS. However, the 4-m walk test has been used extensively in

previous large epidemiological studies which have confirmed its concurrent and predictive validity.¹⁷ Our pervasive study also found meter/time (m/s) was no different between 4-m walk test and 6-m walk test (Bai huijing and colleagues unpublished). Our study is limited to residents of Shanghai and future studies are needed to increase sampling in areas such as northern China and other urban areas to confirm current findings.

In conclusion, skeletal muscle mass and muscle function decreases with age. The loss of muscle strength and gait speed is greater than the decline of muscle mass. In the upper limb, the change of muscle strength was greater than the change of muscle mass in men but the opposite trend was found for women. Women are more prone to have low muscle mass than the men based on the muscle mass index. Low muscle mass and muscle strength are associated with a lower level of physical activity, with alcohol consumption and smoking. Our results suggest that efforts to improve the functional capacity of the elderly should consider gender differences. Exercise programs for men should be set more to target functional movement of upper limbs while for women the focus should be more on increasing muscle mass and functional movement in the lower limbs to reduce the risk of sarcopenia.

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AUTHOR DISCLOSURES

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Original Article

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中国上海老年人骨骼肌肌量与功能随年龄下降的横断面研究

目的：探讨与年龄相关的骨骼肌肌量与功能之间的关系。**方法：**本研究包括415名年龄在60~99岁之间的受试者。采用人体成分仪测量上肢和下肢骨骼肌肌量、去脂组织。四肢骨骼肌肌量指数=四肢骨骼肌肌量/身高平方。采用握力与步速评价骨骼肌功能。**结果：**老年男性、女性骨骼肌肌量低于切点值的比例分别是（23.6% vs 33.5%， $p=0.025$ ）。老年男性随年龄的增加握力（ $\beta=-0.809$ ）下降快于上肢骨骼肌肌量（ $\beta=-0.592$ ），但在老年女性中不存在同样的情况（ $\beta=-0.389$ 和 $\beta=-0.486$ ）。在老年男性（ $\beta=-0.683$ vs $\beta=-0.442$ ）与女性（ $\beta=-1.00$ vs $\beta=-0.461$ ）中，步速下降快于下肢骨骼肌肌量。老年男性与女性上肢骨骼肌肌量与握力的决定系数是28~29%，下肢骨骼肌肌量与步速的决定系数是（7~8%）。除体重指数与年龄外，吸烟、运动和受教育情况与四肢骨骼肌肌量、去脂组织相关。吸烟、饮酒与握力呈负相关（ $p<0.05$ ）。**结论：**老年男性上肢骨骼肌功能下降快于骨骼肌肌量。然而，老年女性骨骼肌肌量低于切点值的百分比大于男性。运动方案的制定需要考虑性别的因素。

关键词：肌肉衰减综合征、骨骼肌肌量、骨骼肌力量、骨骼肌功能、老年人