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Implication of Sarcopenia and Sarcopenic Obesity on Lung Function in Healthy Elderly: Using Korean National Health and Nutrition Examination Survey

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Previous studies have demonstrated a positive association between obesity and decreased lung function. However, the effect of muscle and fat has not been fully assessed, especially in a healthy elderly population. In this study, we evaluated the impact of low muscle mass (LMM) and LMM with obesity on pulmonary impairment in healthy elderly subjects. Our study used data from the Korea National Health and Nutrition Examination Survey from 2008 to 2011. Men and women aged 65 yr or older were included. Muscle mass was measured by dual-energy X-ray absorptiometry. LMM was defined as two standard deviations below the sex-specific mean for young healthy adults. Obesity was defined as body mass index ≥ 25 kg/m^2. The prevalence of LMM in individuals aged over 65 was 11.9%. LMM and pulmonary function (forced vital capacity and forced expiratory volume in 1 second) were independently associated after adjusting for age, sex, body mass index, smoking status, alcohol consumption, and frequency of exercise. LMM with obesity was also related to a decrease in pulmonary function. This study revealed that LMM is an independent risk factor of decreased pulmonary function in healthy Korean men and women over 65 yr of age.

Keywords: Low Muscle Mass; Obesity; Respiratory Function Tests; Aged; Body Mass Index

INTRODUCTION

As aging progresses, body composition also changes and is characterized by gain of fat mass and loss of skeletal muscle mass, a condition referred to as sarcopenia (1). Sarcopenia maintains a chronic inflammatory state, causes chronic disease, and ultimately increases mortality (2,3).

Previous studies have demonstrated that decreased pulmonary function leads to not only respiratory disease but also cardiovascular and cerebrovascular disease even in healthy elderly people (4,5). Many factors may contribute to pulmonary function. Age, sex, smoking status, physical performance, and comorbidities such as pulmonary disease are important factors affecting pulmonary function (6). Many studies have reported an association between obesity and lung function. However, the association of obesity and pulmonary function is controversial, and the mechanism by which obesity (increased fat mass and decreased muscle mass) impairs lung function is not clearly understood. Hence, age-related sarcopenia and lung function impairment observed in old age could be related.

In men with chronic respiratory disorders such as chronic obstructive pulmonary disease (COPD), body weight, especially lean body mass and obesity, are related to respiratory muscle strength and pulmonary function (7,8). Muscle strength, especially in quadriceps muscles, is an important factor of physical performance and quality of life in COPD patients (9). A study that investigated the relationship between peripheral muscle strength and pulmonary function in elderly men from a nursing home found that handgrip strength is positively associated with maximal pulmonary pressure and maximal expiratory pressure (10).

A high proportion of patients admitted to a hospital for the first time with acute exacerbation have not been previously diagnosed as having lung disease (11). Evaluation of lung function and modifiable risk factors related to impaired lung function are important in healthy elderly individuals who have not been previously diagnosed with lung disease. Sarcopenia may be associated with pulmonary function not only in COPD and elderly patients with major comorbidities but also in healthy elderly men and women without lung disease diagnoses. The elderly can easily acquire acute pulmonary infections, such as acute bronchiolitis or pneumonia. Additionally, these pulmonary infections lead to atelectasis and respiratory complications more easily in the elderly than in young adults even if the latter do not have a prior history of lung disease. The aim of this study was to evaluate the association between muscle mass and pulmonary function in healthy Korean men and women aged 65 yr or older.

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MATERIALS AND METHODS

Study population

The Korea National Health and Nutrition Examination Survey (KNHANES) is a nationally representative, population-based cross-sectional survey, which includes data since 1998 as reported by the Korea Centers for Disease Control and Prevention. A stratified, multistage probability sampling design was used to select the survey population. The survey consisted of a health interview, nutritional questionnaires, and health examinations. A pulmonary function test (PFT) was performed for adults aged more than 40 yr, and dual-energy x-ray absorptiometry (DXA) was performed to determine body composition in subjects aged more than 10 yr from 2008 to 2010. Our study was conducted using KNHANES data from 2008 to 2010.

Men and women older than 65 yr who underwent a health examination, PFT, and DXA were enrolled in our study. The subjects with pulmonary diseases such as COPD, bronchiectasis, asthma, and active tuberculosis were excluded. Participants with decreased lung function, defined as a forced expiratory volume in 1 second (FEV_1)/forced vital capacity (FVC) ratio of < 0.7, were also excluded to eliminate COPD interference. In addition, individuals with chronic diseases such as chronic kidney disease and liver cirrhosis and those with a history of stroke, myocardial infarction, or malignancy were also excluded. A total of 1,583 subjects were finally enrolled.

Definitions of low muscle mass and low muscle mass with obesity

Whole-body muscle mass, fat, and bone mass were measured by DXA. Appendicular skeletal muscle mass (ASM) was calculated as the sum of the muscle masses of the arms and legs. Low muscle mass (LMM) was defined as a value of ASM divided by weight (ASM/Wt, %) that was two standard deviations below the sex-specific mean of the young reference group (12,13). The reference group comprised healthy individuals aged 20-39 yr who were involved with KNHANES during the same period as the subjects were analyzed, excluding those with any malignancy, stroke, myocardial infarction, angina, chronic kidney disease, liver cirrhosis, hypertension, diabetes mellitus, asthma, or active tuberculosis. Finally, 2,292 men and 3,157 women were included in the reference group.

Obesity was defined as a body mass index (BMI) greater than 25 kg/m^2 based on the World Health Organization recommendation for Asian population-based classification (14). Furthermore, LMM with obesity was defined as the combination of LMM and obesity.

Pulmonary function test

A PFT was conducted by a trained technician using a dry rolling-seal spirometer, according to the American Thoracic Society guidelines (15). Spirometry was repeated from a minimum of three times to a maximum of eight times in each subject to ensure acceptability and reproducibility, and the best FVC and FEV_1 values were recorded. The predicted FVC and FEV_1 values were determined by comparison with the Korean reference values reported by Choi et al. (16).

Statistical analysis

All analyses were conducted using weighted values, which were calculated according to the number of subjects in each research year and the research category to represent a residential Korean population. Continuous variables were calculated by a complex samples general linear model and presented as the mean ± standard error (SE). Categorical variables were analyzed by complex samples logistic regression analysis presented as the estimated proportion (SE). To assess the relationship between LMM and pulmonary function, complex samples logistic regression analyses were performed, using SPSS version 20.0 (IBM, New York, NY, USA). P values of < 0.05 were considered statistically significant.

Ethics statement

Written informed consent was given by all participants and the protocol for KNHANES IV and V were approved by the institutional review board of the KCDC (2008-04EXP-01-C, 2009-01CON-03-2C, 2010-02CON-21-C, 2011-02CON-06-C). The present study did not require additional review and approval because the KNHANES data set is publicly available.

RESULTS

General characteristics of the participants

The study population comprised 635 men and 948 women. The cutoff points for LMM were 27.85% in men and 21.35% in women according to the definition adopted. The estimated prevalence of LMM in Koreans aged ≥ 65 yr was 11.9% (n = 167). The general characteristics of the subjects are shown in Table 1. The mean age in the LMM group (73.7 yr) was higher than that in the normal muscle mass group (71.9 yr, P < 0.001). Because of age differences between the two groups, other demographic data are adjusted for age. Sex distributions were similar in the normal muscle mass and LMM groups (P = 0.460). Current smokers comprised 24.7% and 18.3% of the normal muscle mass and LMM groups, respectively; this difference was not statistically significant (P = 0.270).

Pulmonary function according to muscle mass status

Compared with the normal muscle mass group, the LMM group had decreased lung function. Participants with LMM had lower mean FEV_1, FVC, and FVC percentage values than the normal muscle mass group (all P < 0.001). However, the FEV_1/FVC values did not differ significantly between the two groups (P = 0.813). Complex sample logistic regression analysis was performed to determine whether LMM was independently associated with pulmonary function. The results of the analyses are shown in Table 2. After adjusting for age, sex, and BMI, the LMM group showed significantly decreased FEV_1 and FVC compared with the normal muscle mass group (P = 0.010 and P < 0.001, respectively). Similarly, after further adjusting for smoking status, alcohol consumption, and frequency of exercise, the associations of LMM with FVC and FEV_1 were unchanged (P = 0.009 and P < 0.001, respectively).

A scatter plot of ASM/Wt versus lung function parameters (FEV_1, FVC, FEV_1 percentage, FVC percentage, and FEV_1/FVC) adjusted for age are presented in Fig. 1. ASM/Wt showed a significant positive correlation with FEV_1 and FVC (all P < 0.001; R^2 = 0.449 and R^2 = 0.487, respectively).

Table 1. Baseline characteristics of the study population

Parameters	Normal muscle mass	Low muscle mass	P value
Age (yr)	71.92 ± 0.19	73.67 ± 0.41	< 0.001
Sex (male)	37.7 (1.6)	39.2 (4.4)	0.460
Height (cm)	156.44 ± 0.30	155.86 ± 0.71	0.448
Weight (kg)	58.19 ± 0.38	65.52 ± 0.88	< 0.001
Body mass index (kg/m²)	23.69 ± 0.12	27.08 ± 0.37	< 0.001
Waist circumference (cm)	83.28 ± 0.35	93.76 ± 0.86	< 0.001
Body fat (%)	28.29 ± 0.27	38.18 ± 0.76	< 0.001
ASM (kg)	16.08 ± 0.14	14.91 ± 0.29	< 0.001
ASM/Wt (%)	27.52 ± 0.13	22.60 ± 0.33	< 0.001
Smoking			0.270
Never	62.6 (1.6)	63.9 (4.7)	
Former	12.7 (1.2)	17.8 (3.8)	
Current	24.7 (1.5)	18.3 (4.1)	
Alcohol			0.526
None	48.3 (1.8)	56.0 (4.8)	
Once a week or less frequent	32.7 (1.7)	29.1 (4.3)	
More than twice a week	19.0 (1.4)	14.9 (3.1)	
Exercise			0.158
None	65.6 (1.8)	74.1 (4.1)	
Less than two times a week	10.7 (1.1)	10.1 (3.4)	
Three times a week or more	23.8 (1.7)	15.8 (3.1)	

All data are weighted to the residential population of Korea and calculated by complex samples general linear model and complex samples logistic regression analysis. Values are expressed as mean ± standard error or estimated percentage (standard error). ASM, appendicular skeletal muscle mass; Wt, weight.

Effect of LMM with obesity on lung function

Based on our definition of LMM with obesity, its estimated prevalence rates in Koreans aged ≥ 65 yr were 7.8% and 9.6% in men and women, respectively. Furthermore, the estimated prevalence of LMM with normal weight was 4.4% in men and 2.1% in women. The ages were different between the groups, especially in men. In men, the mean ages were 71.5 yr in the normal group, 70.4 yr in the normal muscle mass with obesity group, 75.1 yr in the LMM with normal weight group, and 73.4 yr in the LMM with obesity groups (P < 0.001). In women, the LMM groups were older than the normal muscle mass groups (P = 0.073). Lifestyle parameters such as frequency of smoking, alcohol consumption, and exercise frequency were not different in both sexes.

Pulmonary function (FEV_1 and FVC) differences between the four groups are presented in Fig. 2. After adjusting for age, the mean FEV_1 and FVC values were lower in the LMM groups than in the normal muscle mass groups regardless of obesity status. Furthermore, the LMM with obesity group had more decreased pulmonary function than the LMM with normal weight group in both sexes. In men, the mean FEV_1 values were 2.63 ± 0.02 in the normal groups, 2.56 ± 0.07 in the LMM with normal weight group, and 2.45 ± 0.05 in the LMM with obesity group (P = 0.001). In women, the mean FEV_1 values were 1.92 ± 0.02 and 1.85 ± 0.04 in the normal and LMM with obesity groups, respectively (P = 0.324). The mean FVC values in men were 3.70 ± 0.04 in the normal group, 3.70 ± 0.05 in the normal muscle mass with obesity group, 3.53 ± 0.11 in the LMM with normal weight group, and 3.38 ± 0.08 in the LMM with obesity group (P = 0.001). The mean FVC values in women were 2.50 ± 0.02, 2.49 ± 0.02, 2.45 ± 0.15, and 2.38 ± 0.04 in the respective groups (P = 0.164).

DISCUSSION

This study revealed an association between LMM and pulmonary function in healthy Korean men and women aged ≥ 65 yr. In addition, LMM with obesity was associated with lung function in both sexes.

To our knowledge, this is the first study to evaluate the association between LMM and pulmonary function in healthy elderly men and women. Many studies have investigated the re-

Table 2. Pulmonary function parameters according to muscle mass status

Pulmonary parameters	Normal muscle mass	Low muscle mass	P value	P value*	P value†
FEV_1 (L)	2.21 ± 0.02	2.06 ± 0.04	< 0.001	0.010	0.009
FEV_1 (% predicted)	96.65 ± 0.54	94.50 ± 1.62	0.218	0.172	0.169
FVC (L)	2.96 ± 0.03	2.74 ± 0.06	< 0.001	< 0.001	< 0.001
FVC (% predicted)	91.80 ± 0.48	86.06 ± 1.02	< 0.001	0.012	0.014
FEV_1/FVC	0.75 ± 0.00	0.76 ± 0.01	0.813	0.591	0.624

All data are weighted to the residential population of Korea and calculated by complex samples general linear model and complex samples logistic regression analysis. *Adjusted for age, sex, and body mass index; †Adjusted for age, sex, body mass index, smoking status, alcohol consumption, and frequency of exercise. FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second.

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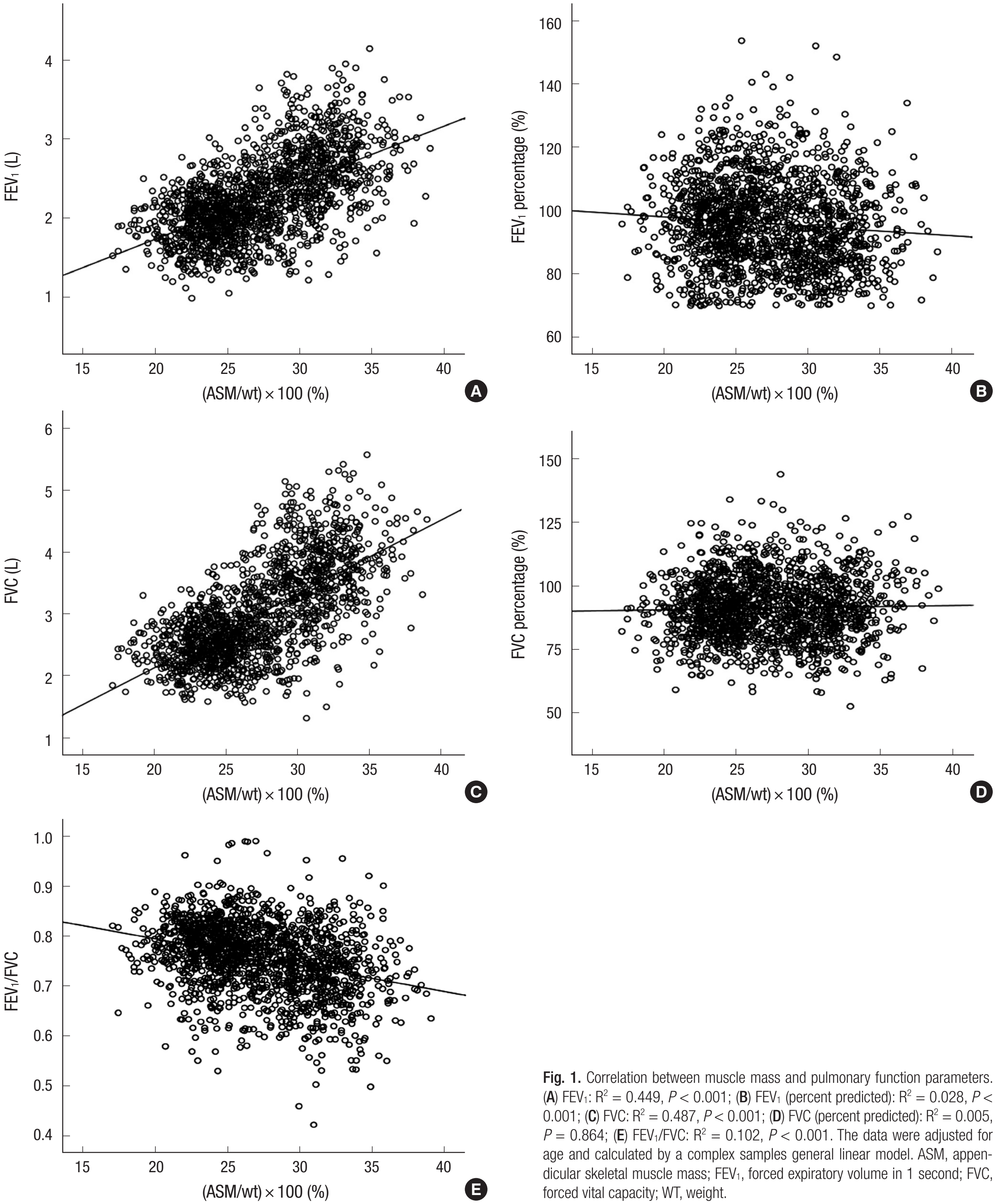

Fig. 1. Correlation between muscle mass and pulmonary function parameters. (**A**) FEV_1: $R^2 = 0.449$, $P < 0.001$; (**B**) FEV_1 (percent predicted): $R^2 = 0.028$, $P < 0.001$; (**C**) FVC: $R^2 = 0.487$, $P < 0.001$; (**D**) FVC (percent predicted): $R^2 = 0.005$, $P = 0.864$; (**E**) FEV_1/FVC: $R^2 = 0.102$, $P < 0.001$. The data were adjusted for age and calculated by a complex samples general linear model. ASM, appendicular skeletal muscle mass; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; WT, weight.

lationship between obesity and pulmonary function. Some indices of obesity, including the combination of height with body weight and other body measurements such as BMI, waist-to-hip ratio, percent body fat, and fat-free mass (FFM), have been studied. The results differ according to the parameters and the definitions of obesity used.

Because of a partial negative association between BMI and mortality in many studies, overweight and obesity were con-

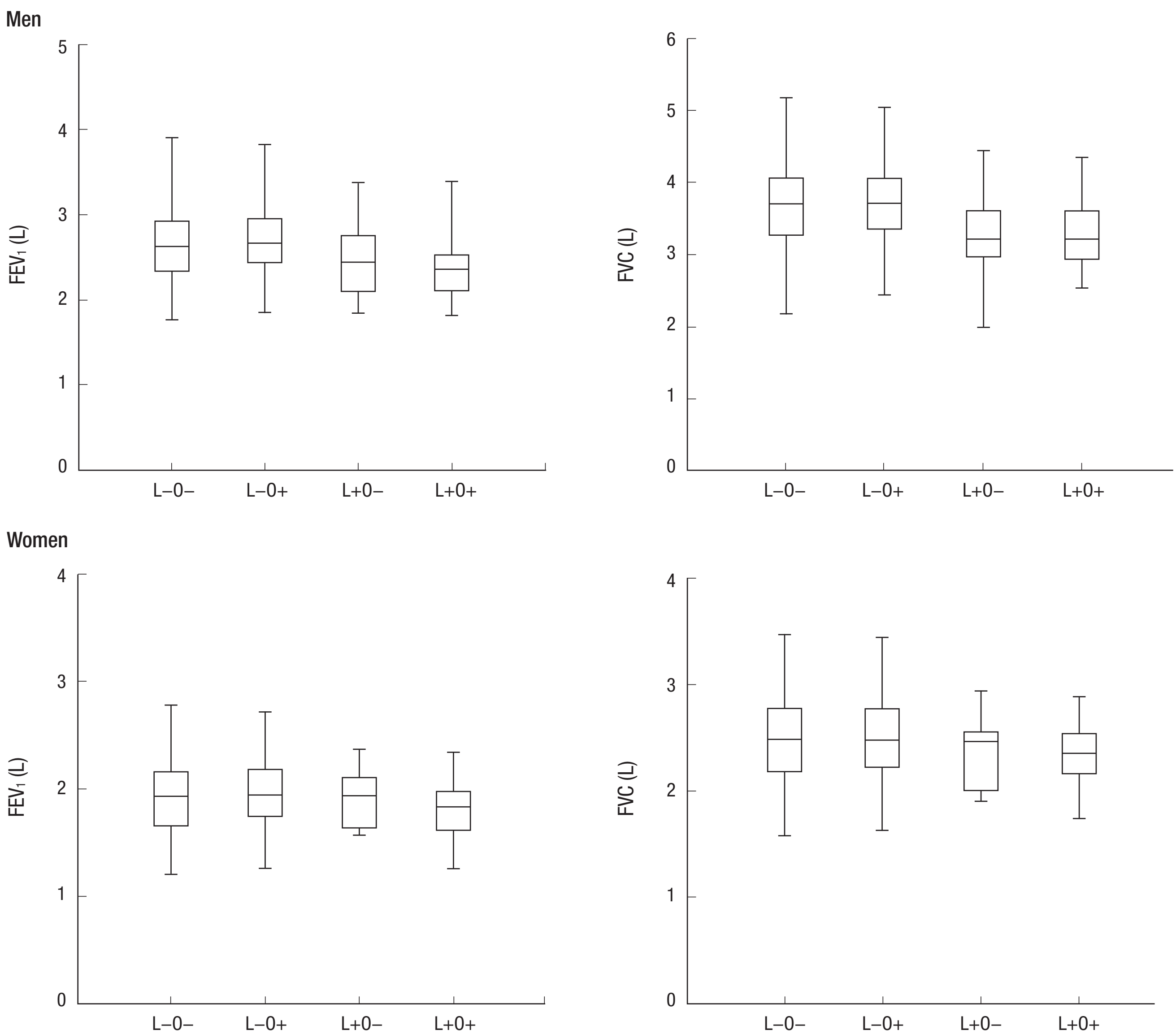

Fig. 2. Comparisons of lung function parameters according to the LMM with obesity status. In men, FEV_1 $P < 0.001$; for FVC $P < 0.001$, in women, FEV_1 $P = 0.324$; for FVC $P = 0.164$. The data were adjusted for age and calculated by a complex samples general linear model. FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second; L–O–, nonsarcopenic nonobese; L–O+, nonsarcopenic obese; L+O–, sarcopenic nonobese; L+O+, sarcopenic obesity.

cluded to be associated with good pulmonary function (17). However, other studies have reported a negative correlation between whole-body fat mass and pulmonary function. Not only the amount of fat mass but also the distribution of fat has been considered an important factor in determining lung function. In elderly men, central fat distribution was found to be negatively associated with lung function with statistical significance, and the amount of muscle mass was positively correlated with lung function (18). A cross-sectional study demonstrated that central fat distribution and lower FFM are related to poorer lung function in the elderly (19). In elderly Japanese-American men, FFM was found to be an independent risk factor of impaired lung function (20). An increased sagittal abdominal diameter and lower FFM were closely related to impaired lung function in elderly men and women in a 7-yr longitudinal study (21).

Obesity causes body fat deposition in the thoracic and abdominal cavities and decreased pulmonary muscle mass, which may be related to changes in pulmonary function (22). In addition, an obese person consumes more oxygen and energy than does a normal-weight individual during respiration. LMM causes a decline in physical performance and physical disability, which are related to decreased lung function. As aging progresses, skeletal muscle mass decreases, and respiratory muscle mass may also decrease. A reduction in diaphragm muscle mass has been demonstrated in aging mice (23). A decrease in peripheral muscle mass may lead to respiratory muscle sarcopenia. However, respiratory muscle sarcopenia has not been well understood.

Interestingly, even after adjusting for smoking status in our

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study subjects, LMM was closely related to respiratory function. This finding is similar to that in the study by Santana et al. (18) who reported an association between body composition and lung function. After excluding the effect of smoking status, FFM was found to be positively correlated with FVC in the same study. The investigation by Lazarus et al. (24) on the association between muscle mass and pulmonary function included only nonsmoking subjects, and the results seem to agree with our study results.

This study has some limitations. First, our study was performed using data from KNHANES, making it a cross-sectional study. As a result, we could not confirm a cause-and-effect relationship between muscle mass and pulmonary function. Second, although muscle mass is well known to be positively correlated with muscle power and function (25), the definition of sarcopenia according to the Asian and European Working Group on Sarcopenia in Older People is the presence of both LMM and low muscle strength or impaired performance (26,27). Not only muscle mass but also muscle function is important for disease prevention and quality of life in the elderly. In this study, however, we evaluated only muscle mass. Third, the amount of muscle and fat mass, as well as the distribution of muscle and fat, is important in determining lung function in the elderly. Our study was unable to evaluate the effects of muscle and fat distribution on lung function. Fourth, the present study was not able to provide estimations on subject symptoms. Accordingly, further studies are needed to overcome these limitations, especially assessment of muscle function such as measuring handgrip or quadriceps power is required.

In conclusion, the present study suggests that in healthy elderly people, muscle mass is positively correlated with pulmonary function. Specifically, LMM and LMM with obesity are strongly associated with impaired lung function. Regular exercise and diet modification to maintain muscle mass may be helpful in sustaining lung function in the elderly.

DISCLOSURE

All authors have no potential conflicts of interest to disclose.

AUTHOR CONTRIBUTION

Concept and coordination of the study: Moon JH, Kim HJ. Design of ethical issues: Moon JH, Kim HJ, Kong MH. Acquisition of data: Moon JH, Kong MH. Data review: Moon JH, Kim HJ. Statistical analysis: Moon JH. Kim HJ, Manuscript preparation: Moon JH, Kim HJ. Manuscript approval: all authors.

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