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To cite this article: Ha-Kyeong Won, Yewon Kang, Jin An, Ji-Hyang Lee, Woo-Jung Song, Hyouk-Soo Kwon, You Sook Cho, Hee-Bom Moon, Il-Young Jang & Tae-Bum Kim (2022): Relationship between asthma and sarcopenia in the elderly: a nationwide study from the KNHANES, Journal of Asthma, DOI: [10.1080/02770903.2022.2047716](https://doi.org/10.1080/02770903.2022.2047716)

To link to this article: <https://doi.org/10.1080/02770903.2022.2047716>



Published online: 09 Apr 2022.



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Relationship between asthma and sarcopenia in the elderly: a nationwide study from the KNHANES

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ABSTRACT

Objective: Few studies have investigated the relationship between asthma and sarcopenia. We aimed to examine the relationship between asthma and sarcopenia in a community-dwelling geriatric population, especially regarding lung function and asthma control.

Methods: A cross-sectional dataset from the Korean National Health and Nutrition Examination Survey 2008–2011 was utilized. Data regarding asthma history, age at asthma onset, recent asthma exacerbations, and hospitalization for asthma exacerbations were obtained using structured questionnaires. Appendicular skeletal muscle was calculated as the sum of the skeletal muscle mass, and physical activity was assessed using the International Physical Activity Questionnaire.

Results: Asthma presented an estimated incidence of $6.17 \pm 0.37\%$ in the elderly. Groups were divided and analyzed according to asthma, muscle mass, and physical activity. Sarcopenia was associated with aging, male sex, smoking history, low body mass index (BMI), and reduced lung function with or without asthma. Sarcopenic asthma had a younger onset and reduced physical activity than non-sarcopenic asthma. Obstructive patterns were more frequent in asthmatics exhibiting low or moderate physical activity levels than in those with high activity, but asthma control was not associated with sarcopenia and physical activity. Multivariate logistic regression analyses showed that compared with control, sarcopenic asthma was associated with $FEV1 < 60\%$, and airway obstruction, and with aging, male, and lower BMI, compared with non-sarcopenic asthma.

Conclusions: Our findings suggest that decreased muscle mass and physical activity levels contribute to reduced lung function in elderly asthmatics. Furthermore, sarcopenic asthma was associated with aging, low BMI, and reduced lung function in the elderly.

ARTICLE HISTORY

Received 4 February 2021
Revised 9 February 2022
Accepted 23 February 2022

KEYWORDS

Asthma; elderly; physical activity; sarcopenia; lung function

Introduction

As the global elderly population continues growing, increased morbidity and chronic diseases among these individuals will not only create important socio-economic issues but also increase medical costs for public healthcare systems (1). Meanwhile, several aging-related diseases can elevate the risk of developing other chronic diseases. Previous studies have indicated that muscle mass and physical activity are important for healthy aging (2); hence, maintaining appropriate muscle mass and regular physical activity may lower the risk of developing chronic diseases, such as type 2 diabetes, hypertension, dyslipidemia, osteoporosis,

osteoarthritis, and chronic obstructive pulmonary disease (COPD) (3).

Sarcopenia is a syndrome characterized by decreased skeletal muscle mass and strength; the risk of developing chronic diseases increases with age and is directly associated with physical activity levels, particularly in the elderly (4–6). Although the loss of muscle mass was the main objective of research regarding sarcopenia when first defined, several groups, including the European Working Group on Sarcopenia in Older People (7) and the Asian Working Group for Sarcopenia (AWGS) (8), now recommend measuring muscle strength and physical activity levels in addition to muscle mass to diagnose sarcopenia.

Meanwhile, the prevalence of asthma, an obstructive airway disease, has markedly increased in the geriatric population in recent years (9). Asthma in the elderly is also considered an important health problem as it is associated with higher rates of morbidity and mortality and poorer prognoses, that is, under-diagnosis and under-treatment, than in younger patients (10–12). According to a recent study using the National Health Insurance database, the prevalence of asthma in the Korean community in Korea was confirmed to be 1.55–2.21%, but with recent increases in the elderly population to approximately 16.5% in 2021, geriatric asthma has become more prevalent, and the proportion of the elderly with severe asthma has been increasing (13). Moreover, asthma in the elderly decreases the quality of life and increases socioeconomic burdens (14,15).

Various published studies have indicated that sarcopenia is associated with the occurrence and induction of chronic diseases in the existing elderly population. Several studies have explored the relationship between COPD and sarcopenia, including prognosis and lung function (16–18). Furthermore, according to a recent meta-analysis, the prevalence of sarcopenia was approximately 13.1% in individuals aged ≥ 65 years in the Korean population (19). However, to the best of our knowledge, no study has reported on the relationship between asthma and sarcopenia, particularly regarding changes in skeletal muscle mass and physical activity in elderly asthmatics, especially those living in the community.

Accordingly, we hypothesized through this study that sarcopenia, which is a decrease in muscle mass or physical activity levels in the older individuals, can affect lung function and asthma control, including asthma exacerbation and lung function decline. In the present study, we aimed to explore the relationships of asthma with sarcopenia, and physical activity in a geriatric population nationwide.

Materials and methods

Study population

In the present study, we utilized cross-sectional registry study databases from the Korean National Health and Nutrition Examination Survey (KNHANES) 2008–2011. The KNHANES is a national dataset representative of the civilian and non-institutionalized Korean population that contains data collected annually via systematic sampling using complex and multistage stratification since 1998 by the Korea Disease Control and Prevention Agency (KDCA). Trained interviewers and laboratory technicians perform the related

surveys. Further details regarding the KNHANES can be accessed on <https://knhanes.cdc.go.kr/knhanes/eng/> (20). Among the 37753 participants in the KNHANES 2008–2011, those aged < 65 years and those without asthma questionnaire replies were excluded. 6012 participants aged 65 or more were initially included in the present study. Among this population, according to the results, 4116 participants were analyzed excluding cases where data related to muscle mass and physical activity were unavailable. The protocol of this study was approved by the Institutional Review Board of the KDCA. All participants were fully informed of the protocol and provided a written informed consent.

Definitions of asthma, lung function, and parameters

The following asthma-related questions were asked: “Have you ever been diagnosed with asthma by a physician? (Asthma)” and “If so, how old were you when you were diagnosed? (Age at asthma onset)” Asthma-specific history was obtained using the following questions: “Have you been hospitalized for an acute exacerbation of asthma? (History of admission due to asthma exacerbation)” and “Have you experienced an acute asthma exacerbation in the last 12 months? (Recent history of acute asthma exacerbation)”

Lung function was measured using a dry rolling-seal spirometer (Model 2130; SensorMedics; Yorba Linda, CA, USA) based on the American Thoracic Society/European Respiratory Society recommendations (21); specifically, forced expiratory volume in 1 s (FEV1) and forced vital capacity (FVC) were assessed. Spirometry testing was repeated three to eight times to validate the results. Choi's equations used age, sex, height, and weight to calculate the predicted values of FEV1 and FVC (22).

Demographic parameters, including age, sex, smoking status, and body mass index (BMI), were also recorded. BMI was calculated as weight divided by height squared (kg/m^2), and smoking status was classified as never, former, and current; “never” indicated participants who had never smoked or who had smoked fewer than 100 cigarettes; “former” indicated participants who had stopped smoking for six months or more, but who had smoked more than 100 cigarettes; “current” included participants who smoked at the time of the study or stopped within the past six months.

Definition of sarcopenia and physical activity

The whole-body composition was measured using dual-energy x-ray absorptiometry (Discovery W fan-beam densitometer, Hologic, Inc., Bedford, MA,

USA). Appendicular skeletal muscle (ASM) mass was calculated as the sum of the skeletal muscle masses of the upper and lower extremities, without bone and fat tissue. The ASM mass index (ASMMI) was calculated as ASM (kg) divided by height in square meter (m^2), as height is known to be a confounding factor of pulmonary function (23). Based on the recommendations of the AWGS (8), sarcopenia was defined as an ASMMI of at least $7.0 \text{ kg}/m^2$ for males and $5.4 \text{ kg}/m^2$ for females.

The level of physical activity corresponded to the metabolic equivalents (METs) and was determined using the International Physical Activity Questionnaire (24). METs were defined as the ratio between the metabolic rate during a specific physical activity and the reference metabolic rate, calculated as follows:

$$\text{MET level of each activity} \times \text{minutes of activity} \\ \times \text{times per week of activity}$$

Walking and moderate and vigorous activities were multiplied by 3.3, 4.0, and 8.0, respectively, to obtain the MET level (24). Physical activity was divided into tertiles based on the MET level per week and was classified as low, moderate, and high levels in the study population.

Statistical analysis

Data are presented as the mean or proportion $\pm$ standard errors (SE) according to their parameter

characteristics. The Chi-square test was used to examine the associations between categorical variables. Univariate and multivariate logistic regression analyses were performed to investigate the relationship of asthma with sarcopenia and physical activity levels.

To obtain unbiased national estimates representative of the elderly Korean population, we adjusted the KNHANES sampling weight to account for the complex sample design. Sampling was applied to strata at the level of primary sampling units and households. The missing data were assumed to be randomly missing, and all data were considered valid in all analyses. A two-sided p values < 0.05 was considered statistically significant. All statistical analyses were performed using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Baseline characteristics for participants with and without asthma in the elderly population

Table 1 compares the baseline characteristics of participants with and without asthma. An estimated $6.17 \pm 0.37\%$ of participants had asthma. Those with asthma were older, predominantly female, and were more likely to be obese with a higher BMI ($\geq 25.0 \text{ kg}/m^2$) and a greater total fat mass, than those without asthma. They also exhibited with lower lung function,

Table 1. Baseline characteristics of elderly with and without asthma in the KNHANES 2008–2011.

	With asthma ($n = 372$)	Without asthma ($n = 5640$)	p value
Estimated proportion (%)	6.17 ± 0.37	93.83 ± 0.37	
Age (years)	73.70 ± 0.38	72.81 ± 0.10	0.024
Age at asthma onset (years)	59.73 ± 1.02	—	
Male sex (%)	33.22 ± 2.90	41.38 ± 0.66	0.009
Smoking status (%)			0.688
Never	55.91 ± 3.18	58.54 ± 0.75	
Former	30.03 ± 3.04	27.55 ± 0.69	
Current	14.06 ± 2.22	13.90 ± 0.59	
BMI (kg/m^2)	24.17 ± 0.24	23.67 ± 0.06	0.042
BMI category (%)			0.037
$< 18.5 \text{ kg}/m^2$	6.29 ± 1.70	4.72 ± 0.35	
$18.5\text{--}24.9 \text{ kg}/m^2$	55.08 ± 3.10	64.60 ± 0.76	
$25.0\text{--}29.9 \text{ kg}/m^2$	34.10 ± 3.07	27.43 ± 0.76	
$\geq 30.0 \text{ kg}/m^2$	4.53 ± 1.37	3.25 ± 0.31	
FEV1 (L)	1.69 ± 0.05	2.13 ± 0.01	< 0.001
FEV1 pred. (%)	77.88 ± 2.23	93.02 ± 0.41	< 0.001
FEV1 $\geq 80\%$		77.43 ± 0.88	
$60\% \leq \text{FEV1} < 80\%$		18.65 ± 0.81	
FEV1 $< 60\%$		3.92 ± 0.43	
FEV1/FVC ratio	0.65 ± 0.01	0.74 ± 0.00	< 0.001
History of admission d/t AE-asthma	6.71 ± 1.83	—	
Recent history of AE-asthma	20.07 ± 3.37	—	
ASM/Ht ² (kg/m^2)	6.25 ± 0.07	6.40 ± 0.02	0.027
Total fat mass (kg)	7.24 ± 0.19	6.68 ± 0.06	0.006

BMI, body mass index; FEV1, forced expiratory volume in 1 s; pred., predicted; FVC, forced vital capacity; d/t, due to; AE, asthma exacerbation; ASM, appendicular skeletal muscle; Ht, height.

Data are presented as estimated means or proportions $\pm$ standard error.

more obstructive patterns, and less muscle mass than their counterparts. Based on differences in muscle mass between those with and without asthma, we classified the study population into those with and without sarcopenia according to muscle mass (Table 2).

Sarcopenia in elderly asthmatics

Asthmatics with sarcopenia tended to be older, had a younger age of asthma onset, were predominantly male, and were more likely to be former or current smokers than those without sarcopenia (Table 2). Those presenting early-onset asthma (<18 years) comprised 1.18% of the study population, which was mainly composed of patients with late-onset asthma (data not shown). Moreover, asthmatics with sarcopenia had a lower FEV1, more obstructive patterns, and lower physical activity levels. Even in sarcopenic cases without asthma, the variables showed the same tendency as those in sarcopenic asthma, except for FEV1 (L) and vigorous activity (vs. non-sarcopenia without asthma). In addition, the sarcopenic asthma group presented with more frequent asthma exacerbations and hospitalizations due to asthma exacerbations than the non-sarcopenic asthma group, although this difference was insignificant. The sarcopenic asthma group was significantly associated with a lower level of total physical activity (METs) than the

non-sarcopenic asthma group, particularly with vigorous activity (305.69 ± 43.27 vs. 465.09 ± 48.34 METs, $p = 0.024$) levels. Based on differences in physical activity levels between sarcopenia and non-sarcopenia groups, we divided elderly participants with and without asthma into three different physical activity level groups (Table 3).

Differences according to physical activity levels in elderly asthmatics

Asthmatics with low or moderate physical activity levels were more likely to have more airflow limitations when compared with their highly active counterparts. No associations were detected with age, age at asthma onset, sex, smoking status, obesity, or skeletal muscle mass. Although ASMMI did not differ according to physical activity levels among elderly asthmatics, those in the low activity group were significantly more prone to have sarcopenia than those in the high activity group (shown in Figure 1).

Conversely, in the elderly population without asthma, there were differences in age, sex ratio, smoking history, ASMMI, and total fat mass according to physical activity. Moreover, we noted a significant difference in FEV1, but there were no significant differences in airflow limitation.

Table 2. Differences between sarcopenia and non-sarcopenia according to muscle mass in the elderly.

	Sarcopenia without asthma (n = 1210)	Non-sarcopenia without asthma (n = 2676)	p value	Sarcopenic asthma (n = 84)	Non-sarcopenic asthma (n = 146)	p value
Estimated proportion (%)	31.66 ± 1.01	68.34 ± 1.01		34.12 ± 3.52	65.88 ± 3.52	
Age (years)	73.77 ± 0.22	72.10 ± 0.15	<0.001	74.42 ± 0.85	72.61 ± 0.51	<0.001
Age at asthma onset (years)	—	—		57.76 ± 1.83	59.43 ± 1.69	<0.001
Male sex (%)	56.58 ± 1.7	34.64 ± 1.11	<0.001	58.75 ± 6.81	18.71 ± 3.55	<0.001
Smoking status (%)			<0.001			<0.001
Never	45.13 ± 1.71	64.57 ± 1.15		34.06 ± 5.97	73.31 ± 4.76	
Former	34.91 ± 1.53	24.55 ± 1.06		44.45 ± 6.74	16.83 ± 4.15	
Current	19.97 ± 1.49	10.88 ± 0.67		21.49 ± 5.48	9.86 ± 2.66	
BMI (kg/m ²)	21.37 ± 0.09	24.68 ± 0.08	<0.001	21.63 ± 0.39	25.60 ± 0.32	<0.001
FEV1 (L) (n = 4112)	2.12 ± 0.03	2.17 ± 0.02	0.119	1.61 ± 0.10	1.76 ± 0.05	<0.001
FEV1 pred. (%) (n = 4112)	90.33 ± 0.9	94.54 ± 0.58	0.001	71.84 ± 6.00	83.47 ± 2.37	<0.001
FEV1 ≥ 80%	71.27 ± 2.65	83.44 ± 1.35		46.31 ± 12.3	69.7 ± 5.6	
60% ≤ FEV1 < 80%	24.38 ± 2.55	14.04 ± 1.21		10.81 ± 5.52	21.23 ± 4.75	
FEV1 < 60%	4.35 ± 1.29	2.52 ± 0.61		42.88 ± 11.78	9.07 ± 3.04	
FEV1/FVC ratio (n = 4112)			<0.001			0.002
FEV1/FVC < 0.7	33.35 ± 2.78	22.74 ± 1.45		83.72 ± 4.26	44.51 ± 6.69	
History of admission d/t AE-asthma	—	—		9.17 ± 4.48	6.86 ± 3.18	0.675
Recent history of AE-asthma	—	—		29.28 ± 8.41	18.16 ± 5.16	0.258
ASM/Ht ² (kg/m ²)	5.81 ± 0.03	6.67 ± 0.02	<0.001	5.78 ± 0.09	6.50 ± 0.08	<0.001
Total fat mass (kg)	5.69 ± 0.09	7.13 ± 0.07	<0.001	5.97 ± 0.29	7.94 ± 0.22	<0.001
IPAQ						
Total physical activity level, METs min/week	369.59 ± 16.96	356.44 ± 10.56	0.496	305.69 ± 43.27	465.09 ± 48.34	0.024
Low activity, hour/week	4.8 ± 0.20	4.34 ± 0.13	0.057	3.76 ± 0.51	4.95 ± 0.61	0.142
Moderate activity, hour/week	2.92 ± 0.34	2.96 ± 0.16	0.918	3.40 ± 2.42	3.49 ± 0.52	0.89
Vigorous activity, hour/week	4.45 ± 0.87	3.51 ± 0.38	0.345	1.02 ± 1.05	9.48 ± 2.55	0.004

BMI, body mass index; FEV1, forced expiratory volume in 1 s; pred., predicted; FVC, forced vital capacity; d/t, due to; AE, asthma exacerbation; ASM, appendicular skeletal muscle; Ht, height; IPAQ, the International Physical Activity Questionnaire; METs, metabolic equivalents.

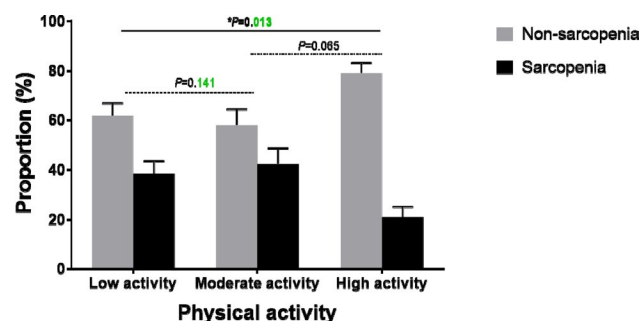
Data are presented as estimated means or proportions ± standard errors.

Table 3. Differences in the elderly with and without asthma according to physical activity.

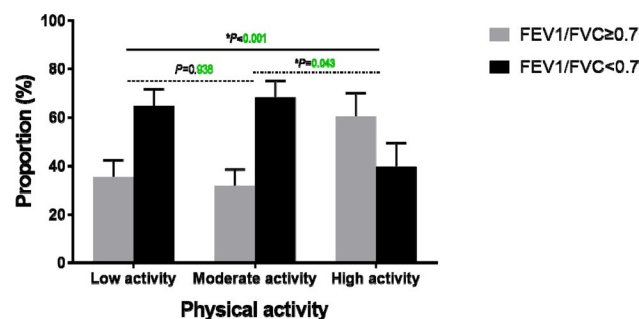
	The elderly without asthma				The elderly with asthma			
	Low activity (n = 1495)	Moderate activity (n = 1240)	High activity (n = 1151)	p value	Low activity (n = 78)	Moderate activity (n = 80)	High activity (n = 72)	p value
Estimated proportion (%)	38.47 ± 1.11	31.9 ± 1.03	29.63 ± 0.94		34.15 ± 3.77	34.75 ± 3.76	31.1 ± 3.92	
Age (years)	71.34 ± 0.17	72.68 ± 0.22	72.72 ± 0.19	<0.001	72.6 ± 0.65	73.7 ± 0.55	71.38 ± 0.42	0.334
Age at asthma onset (years)	—	—	—		59.37 ± 1.79	58.51 ± 1.59	55.78 ± 1.38	0.247
Male sex (%)	52.62 ± 1.32	36.54 ± 1.75	41.88 ± 1.59	<0.001	41.76 ± 6.04	36.68 ± 6.07	22.3 ± 4.54	0.076
Smoking status				<0.001				0.569
Never	49.7 ± 1.51	63.31 ± 1.91	59.56 ± 2.0		54.84 ± 6.26	58.13 ± 6.61	67.83 ± 4.38	
Former	33.43 ± 1.49	24.41 ± 1.66	29.32 ± 1.75		31.29 ± 5.7	23.18 ± 5.25	21.02 ± 4.51	
Current	16.87 ± 1.25	12.28 ± 1.42	11.11 ± 1.24		13.87 ± 4.68	18.69 ± 5.37	11.15 ± 3.17	
BMI (kg/m ²)	23.51 ± 0.1	23.76 ± 0.13	23.77 ± 0.12	0.083	24.06 ± 0.37	23.89 ± 0.79	24.54 ± 0.34	0.515
BMI category (%)				0.229				0.622
<18.5 kg/m ²	4.13 ± 0.65	4.84 ± 0.79	3.64 ± 0.72		5.42 ± 2.24	12.14 ± 6.58	4.02 ± 2.78	
18.5–24.9 kg/m ²	67.8 ± 1.58	62.73 ± 1.8	64.85 ± 1.79		55.72 ± 6.61	49.98 ± 7.04	52.29 ± 5.37	
25.0–29.9 kg/m ²	25.57 ± 1.55	29.41 ± 1.77	27.46 ± 1.56		33.98 ± 6.28	28.91 ± 6.23	40.34 ± 5.07	
≥30.0 kg/m ²	2.5 ± 0.53	3.01 ± 0.69	4.05 ± 0.76		4.88 ± 2.64	8.98 ± 5.2	3.35 ± 1.48	
FEV1 (L) (n = 4112)	2.31 ± 0.02	2.12 ± 0.02	2.16 ± 0.03	<0.001	1.88 ± 0.09	1.73 ± 0.5	1.64 ± 0.04	0.101
FEV1 pred. (%) (n = 4112)	92.42 ± 0.84	92.89 ± 1.0	94.25 ± 1.05	0.198	81.3 ± 2.8	77.31 ± 3.49	77.94 ± 1.23	0.621
FEV1 ≥ 80%	79.83 ± 2.17	79.81 ± 2.14	80.14 ± 2.33	0.924	62.96 ± 5.17	66.64 ± 12.19	56.37 ± 7.66	0.547
60% ≤ FEV1 < 80%	16.49 ± 1.74	17.43 ± 2.02	17.27 ± 2.16		13.51 ± 4.49	11.15 ± 4.3	26.9 ± 6.62	
FEV1 < 60%	3.67 ± 0.98	2.76 ± 1.01	2.59 ± 0.9		23.53 ± 5.71	22.21 ± 11.26	16.73 ± 1.16	
FEV1/FVC ratio (n = 4112)				0.733				0.09
FEV1/FVC < 0.7	26.66 ± 2.22	26.34 ± 2.44	24.18 ± 2.72		67.14 ± 6.18	66.04 ± 8.54	41.45 ± 7.67	
History of admission d/t	—	—	—		0	7.14 ± 5.79	12.92 ± 1.66	0.165
AE-asthma (%)								
Recent history of	—	—	—		19.79 ± 2.22	13.06 ± 6.56	20.81 ± 3.76	0.506
AE-asthma (%)								
ASM/Ht ² (kg/m ²)	6.64 ± 0.03	6.33 ± 0.03	6.43 ± 0.04	<0.001	6.3 ± 0.09	6.24 ± 0.11	6.32 ± 0.1	0.862
Total fat mass (kg)	6.32 ± 0.08	6.85 ± 0.1	6.79 ± 0.11	<0.001	7.39 ± 0.32	6.83 ± 0.46	7.52 ± 0.31	0.985

BMI, body mass index; FEV1, forced expiratory volume in 1 s; pred., predicted; FVC, forced vital capacity; d/t, due to; AE, asthma exacerbation; ASM, appendicular skeletal muscle; Ht, height.

Data are presented as estimated means or proportions ± standard errors.

**Figure 1.** The proportions of participants with sarcopenic asthma according to physical activity levels among elderly asthmatics (n = 230).

When comparing lung function in elderly asthmatics according to physical activity, we observed that few participants with high physical activity levels presented with an FEV1 < 60% when compared with those with low or moderate physical activity levels (proportion ± SE of participants in each group with an FEV1 < 60%: 23.53 ± 5.71%, 22.21 ± 11.26%, and 16.73 ± 1.16% respectively), although this difference was insignificant (low vs. moderate, $p=0.934$; moderate vs. high, $p=0.325$; low vs. high, $p=0.384$). In addition, in elderly asthmatics with sarcopenia, highly active individuals were significantly less likely to have

**Figure 2.** Comparison of airflow limitations according to physical activity levels among elderly asthmatics (n = 230) (FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity).

fixed airway obstructions than those with low or moderate activity levels (shown in Figure 2).

Factors associated with sarcopenic asthma in the elderly

We investigated the factors associated with sarcopenic asthma by examining and comparing the baseline characteristics of three different groups (vs. non-sarcopenia without asthma, sarcopenia without asthma, and non-sarcopenic asthma; data not shown) using

Table 4. Factors associated with sarcopenic asthma in multivariate logistic regression analyses.

	Adjusted OR (95% CI)		Adjusted OR (95% CI)		Adjusted OR (95% CI)	
	Vs. non-sarcopenia without asthma	<i>p</i> value	Vs. sarcopenia without asthma	<i>p</i> value	Vs. non-sarcopenic asthma	<i>p</i> value
Age	1.02 (0.97–1.06)	0.48	1.07 (1.02–1.12)	0.007	1.15 (1.01–1.31)	0.038
Age at asthma onset	–	–	–	–	0.99 (0.96–1.02)	0.626
Male sex	1.54 (0.65–3.68)	0.33	2.32 (0.98–5.49)	0.055	3.21 (1.23–8.39)	0.018
Smoking status						
Never	Reference		Reference		Reference	
Former	2.37 (0.91–6.17)	0.076	2.53 (0.99–6.44)	0.052	2.12 (0.78–5.77)	0.110
Current	1.97 (0.90–4.31)	0.088	1.98 (0.88–4.43)	0.096	1.10 (0.32–3.81)	0.603
BMI	1.05 (0.92–1.2)	0.448	0.65 (0.67–0.74)	<0.001	0.43 (0.29–0.66)	<0.001
FEV1 category						
FEV1 ≥ 80%	Reference		Reference		Reference	
60% ≤ FEV1 < 80%	1.93 (0.65–5.79)	0.239	2.58 (0.82–8.1)	0.103	2.03 (0.36–11.46)	0.708
FEV1 < 60%	28.64 (8.05–101.89)	<0.001	23.3 (6.38–85.04)	<0.001	2.17 (0.45–10.45)	0.594
FEV1/FVC ratio						
FEV1/FVC ≥ 0.7	Reference		Reference		Reference	
FEV1/FVC < 0.7	11.41 (4.07–31.94)	<0.001	8.51 (3.33–21.79)	<0.001	1.58 (0.34–7.22)	0.555
History of admission d/t AE-asthma	–		–		0.39 (0.07–2.01)	0.255
Recent AE-asthma	–		–		1.96 (0.59–6.57)	0.273
Total fat mass (kg)	1.14 (0.83–1.55)	0.418	2.41 (1.8–3.23)	<0.001	0.73 (0.60–0.90)	0.003
Physical activity						
Low activity	Reference		Reference		Reference	
Moderate activity	1.21 (0.6–2.46)	0.592	1.75 (0.84–3.64)	0.136	0.72 (0.12–4.16)	0.708
High activity	0.59 (0.27–1.27)	0.175	0.67 (0.28–1.59)	0.361	0.20 (0.04–1.10)	0.064

BMI, body mass index; FEV1, forced expiratory volume in 1 s; FVC, forced vital capacity; d/t, due to; AE, asthma exacerbation; ASM, appendicular skeletal muscle; Ht, height.

Adjusted for age, sex, smoking status, and BMI.

univariate logistic regression analyses. First, compared with non-sarcopenia without asthma, older age, male sex, smoking history, lower FEV1, airflow limitations, and lower total fat mass were associated with sarcopenic asthma. Second, none of the factors was related to sarcopenic asthma other than lung function (vs. sarcopenia without asthma). Additionally, sarcopenic asthma was positively associated with older age, male sex, former or current smoking, FEV1 < 60%, and more obstructive patterns when compared with non-sarcopenic asthma. Moreover, sarcopenic asthma was negatively associated with a low BMI, low fat mass, and low levels of high physical activity. No associations were found in age at asthma onset, recent asthma exacerbation, or hospitalization due to asthma exacerbation.

In the multivariate logistic regression analysis, compared with non-sarcopenia without asthma, there were no significant variables other than pulmonary function as observed in the univariate analysis. By contrast, aging, lower BMI, an FEV1 < 60%, and airway obstruction were significantly associated with persistent sarcopenic asthma compared with sarcopenia without asthma. Moreover, after adjusting for age, sex, smoking history, and BMI compared with non-sarcopenic asthma, older age, male sex, BMI, and total fat mass were consistently related to sarcopenic asthma, and high activity had a marginal association with them. However, smoking history, lung function, and asthma control were not associated with sarcopenia (Table 4).

Discussion

This study explored the relationships of asthma to both sarcopenia and physical activity among older adults. The results demonstrated that having asthma was associated with older age, female sex, BMI, loss of muscle mass, and increased fat mass when compared with not having asthma in the elderly. Univariate analysis of our study revealed that sarcopenia with and without asthma were associated with male sex, smoking history, and reduced lung function compared with non-sarcopenia. Moreover, in asthmatics, low ASMMI, indicating sarcopenic status, was more correlated with older age, younger onset age, male sex, smoking history, BMI, fat, and lung function than other examined factors. Additionally, a multivariate analysis showed that aging, lower BMI, an FEV1 < 60%, and airway obstruction were significantly associated with sarcopenic asthma. Meanwhile, those participants with low or moderate physical activity levels had more obstructive patterns than their highly active counterparts. Conversely, sarcopenia and physical activity levels in elderly asthmatics were not associated with asthma control, as evidenced by recent asthma exacerbations or hospitalizations due to asthma exacerbations.

To the best of our knowledge, sarcopenia is an age-related condition characterized by reduced muscle mass and decreased strength in the elderly and associated with physical disability, chronic disease, and frailty (25,26). In particular, COPD is well known as

a chronic disease associated with sarcopenia as it induces loss of muscle mass and strength, leading to poor clinical outcomes, including hospitalization and mortality (16,27). An estimated 15% to 55% of patients with COPD have sarcopenia (18,28), these patients have a decreased exercise capacity and physical activity, and a greater airflow limitation, compared to their non-sarcopenic counterparts (16,28). Some studies have demonstrated the association of pulmonary function with muscle mass and function both in healthy elderly subjects and patients with COPD (29,30). The authors found that reduced muscle mass and skeletal muscle dysfunction were related to impaired lung function in both groups. Furthermore, chronic airway diseases, including asthma and COPD, have been recently reported to induce a high sarcopenia prevalence and have an increased odds ratio for obstructive patterns. The group with an FEV1 < 80% showed lower ASMMI and handgrip strength than the group without this value. This finding is in line with the results of our study (31).

Physical inactivity also contributes to sarcopenia (32,33). In other words, several studies have demonstrated that increased physical activity can be associated with elevated muscle mass and strength in the elderly (34,35). In a longitudinal analysis of adult-onset asthma in a Finnish adult asthma cohort (≥ 15 years), daily physical activity was related to long-term higher FEV1 and FEV1/FVC values (36). In patients with moderately or severely persistent asthma aged 20 to 59 years, aerobic training significantly increased the number of asthma symptom-free days and quality of life compared with the aforementioned factors before training (37). Moreover, a recent meta-analysis reported that physical training improved the cardio-pulmonary fitness and quality of life in asthmatics over 18 years of age (38).

However, associations between asthma and sarcopenia, defined according to the muscle mass index and level of physical performance need to be explored further in the community-dwelling geriatric population. In the present study, sarcopenic asthma accounted for approximately one-third ($34.12 \pm 3.52\%$) of community-dwelling older adults with asthma. Compared with non-sarcopenic asthmatics, sarcopenic asthmatics tend to be older males, diagnosed with asthma for a prolonged period and have a relevant smoking history. Moreover, they have a low BMI and total fat mass, decreased lung function, and particularly low activity levels compared with their non-sarcopenic counterparts. According to the results of a previous study, reduced muscle mass or muscle dysfunction affects both impaired lung function and

non-ventilatory muscle, leading to poor outcomes among patients with COPD (30). Although no studies have evaluated how muscle mass can affect lung function and clinical outcomes in asthmatics, our findings suggest that the loss of muscle mass affects lung function decline in sarcopenic asthmatics, particularly in older male patients with a history of smoking and low BMI, as well as in sarcopenic patients with COPD. Moreover, irrespective of the presence of asthma, sarcopenia was found to induce deteriorated pulmonary function and obstructive patterns. Based on these findings, we speculate that reduced muscle mass affects lung function and ventilatory function.

In previous studies, physical activity was shown to prevent sarcopenia (3), and in asthmatics particularly, physical activity was positively associated with lung function and asthma control (36,37). However, we detected a correlation only with airflow limitations, but not with asthma control in this study. These findings may be specific to the age of the study population. The present study consisted of geriatric asthmatics over 65 years of age, whereas previous studies included younger asthmatics. As the elderly present with more comorbid diseases and lower activity than younger adults, the association between physical activity and asthma control may have been affected.

This study has several limitations. First, given the cross-sectional study design, the causal relationships between sarcopenia and asthma-related factors could not be confirmed. Second, as asthma and physical activity-related parameters were self-reported and thus subject to recall bias, they may have been over- or underestimated. Third, data used in this study did not include the muscle strength of participants, thus making it impossible to analyze differences according to muscle strength. Fourth, clinical participants with COPD can be included in the self-reported physician-diagnosed asthma group. One study found that male sex and lung function were significantly associated with sarcopenia in COPD and asthma-COPD overlap groups over 50 years of age, but statistical significance was not obtained in asthmatics (39). Thus, when clinical COPD is excluded, further studies are needed to determine the relationship between sex distribution and lung functions in sarcopenic asthmatics. However, the trend was maintained even on analyzing participants who were considered as never smokers, and both the same trend and statistical significance were obtained in never and former smokers (data not shown). Fifth, as there was no information regarding the use and dose of oral and inhaled corticosteroids

among asthmatics, the associations between corticosteroid treatment in asthmatics and sarcopenia could not be confirmed. Sixth, since the data we used were not recent, the current status of sarcopenia in Korea was not reflected. Therefore, further research is needed using recent data. Finally, racial and geographic differences were not assessed. Nonetheless, this study is the first to investigate the associations between asthma, sarcopenia, and physical activity in community-dwelling asthmatics aged 65 years or older.

Conclusion

Our findings suggest that decreased muscle mass and physical activity levels contribute to reduced lung function in elderly asthmatics, particularly those with airflow limitations. Furthermore, older age, male sex, lower BMI, less fat mass, and low levels of vigorous physical activity were associated with sarcopenic asthma in the aging population, independent of age, sex, smoking, and BMI. From the results of this study, it can be inferred that the early diagnosis of sarcopenia in patients with geriatric asthma may help delay lung function reduction and fixed airway obstruction by monitoring and managing muscle mass and activity. Further studies on these associations ensured by longitudinal analyses are recommended to explain the unknown differences.

Acknowledgements

We are particularly grateful to Heewon Jung and Solmi Kim for their advice on statistical analysis.

Declaration of interest

The authors report no conflict of interest.

Funding

This research was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (grant number: HI19C0481, HC20C0076) and a Veterans Health Service Medical Center Research Grant, Republic of Korea (grant number: VHSMC 20016, 21002).

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