ORIGINAL ARTICLE

Correlation between Physical Activity and Lung Function in Dusty Areas: Results from the Chronic Obstructive Pulmonary Disease in Dusty Areas (CODA) Cohort

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Background: Although physical activity is known to be beneficial to lung function, few studies have been conducted to investigate the correlation between physical activity and lung function in dusty areas. Therefore, the purpose of this study is to investigate the correlation between physical activity and lung function in a Korean cohort including normal and COPD-diagnosed participants.

Methods: Data obtained from the COPD in dusty areas (CODA) cohort was analyzed for the following factors: lung function, symptoms, and information about physical activity. Information on physical activity was valuated using questionnaires, and participants were categorized into two groups: active and inactive. The evaluation of the mean lung function, modified Medical Research Council dyspnea grade scores, and COPD assessment test scores was done based on the participant physical activity using a general linear model after adjusting for age, sex, smoking status, pack-years, height, and weight. In addition, a stratification analysis was performed based on the smoking status and COPD.

Results: Physical activity had a correlation with high forced expiratory volume in 1 second (FEV_1) among CODA cohort (p=0.03). While the active group exhibited significantly higher FEV_1 compared to one exhibited by the inactive group among past smokers (p=0.02), no such correlation existed among current smokers. There was no significant difference observed in lung function after it was stratified by COPD.

Conclusion: This study established a positive correlation between regular physical activity in dusty areas and lung function in participants.

Keywords: Pulmonary Disease, Chronic Obstructive; Physical Activity; Lung Function Test; Smoking

Introduction

World Health Organization (WHO) has reported that 65 million people have a moderate-to-severe chronic obstructive pulmonary disease (COPD) and that COPD will become the third leading cause of death worldwide by 2030[1]. COPD is reportedly characterized by both low lung function and accelerated decline in lung function[2]. With aging, lung function and respiratory muscle strength decrease[3], and most patients with COPD are not diagnosed accurately[4]. Although smoking is a well-known risk factor[5], environmental factors, such as air pollution and occupational exposure, are also crucial risk factors for COPD[6]. Furthermore, exposure to cement dust is

correlated with a higher prevalence of COPD and respiratory symptoms[7].

WHO recommends exercise training programs for managing COPD[8]. Physical activity reduces all-cause cardiovascular and respiratory mortality risk and exacerbation[9,10]. In addition, physical activity has been associated with high lung function in European study[11]. The beneficial effects of physical activity have been reported not only in patients with COPD but also in healthy adults and children[12,13]. Considering environmental pollution and lung health, it is unclear whether exposure to air pollution during physical activity affects the beneficial effects of physical activity. A previous study has reported that air pollution did not affect the beneficial effects of physical activity on reducing the risk of COPD[14]. Furthermore, physical activity positively affected lung function when performed in a highly polluted environment[15]. Studies on physical activity and lung function during air pollution exposure have been reported; however, studies on specific environmental exposures, such as cement dust, are limited.
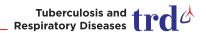
The COPD in dusty areas (CODA) cohort study collected epidemiological and clinical data from participants living near cement plants where cement dust affected them[16]. This study aimed to assess the correlation between physical activity and lung function using the CODA study data to assess the effect

Table 1. Subjects characteristics at the baseline

Characteristic	Total (n=499)	Inactivity (n=385)	Activity (n=114)	p-value
General factor				
Age, yr	72.3±7.3	72.6±7.1	71.0±7.5	0.04
<60	28 (5.6)	19 (4.9)	9 (7.9)	0.34
60–69	115 (23.1)	84 (21.8)	31 (27.2)	
70–79	292 (58.5)	231 (60.0)	61 (53.5)	
≥80	64 (12.8)	51 (13.3)	13 (11.4)	
Sex				
Male	359 (71.9)	262 (68.1)	97 (85.1)	<0.001
Female	140 (28.1)	123 (32.0)	17 (14.9)	
Marriage status				
Single	110 (22.5)	89 (23.7)	21 (18.6)	0.25
Couple	379 (77.5)	287 (76.3)	92 (81.4)	
Income, won				
<500,000	309 (64.4)	244 (66.3)	65 (58.0)	0.27
500,000–1,000,000	78 (16.3)	57 (15.5)	21 (18.8)	
≥1,000,000	93 (19.4)	67 (18.2)	26 (23.2)	
Life style factor				
Smoking status				
Never	185 (37.1)	148 (38.4)	37 (32.5)	0.35
Former	212 (42.5)	157 (40.8)	55 (48.3)	
Current	102 (20.4)	80 (20.8)	22 (19.3)	
Pack-years	17.4±23.3	18.6±24.8	13.6±16.8	0.01
Anthropometric factor				
Height, cm	159.1±9.3	158±9.4	162±8.5	<0.001
Weight, kg	59.6±10.4	58.6±10.5	62.8±9.4	<0.001
Body mass index, kg/m²	23.5±3.2	23.4±3.3	23.9±3.0	0.12
COPD				
No	175 (35.1)	125 (32.5)	50 (43.9)	0.02
Yes	324 (64.9)	260 (67.5)	64 (56.1)	

Values are presented as mean±SD or number (%).
SD: standard deviation; COPD: chronic obstructive pulmonary disease.

of physical activity on lung function a Korean cohort including normal and COPD-diagnosed participants in dusty areas.

Materials and Methods

1. Study design and population

Data from the CODA study were analyzed. The objectives and design of the CODA study have been detailed elsewhere[17]. Briefly, the CODA study enrolled participants living in six areas near cement plants in the Kangwon and Chungbuk provinces of South Korea. Overall, 504 participants (362 males and 142 females) were enrolled between 2012 and 2017 for baseline examinations.

At baseline examinations, data on the medical interview, survey questionnaire, spirometry, physical examination, blood/urine samples, and computed tomography were obtained from all participants. Questionnaire data included demographic factors, lifestyle factors, history of the disease, history of exacerbation, and symptoms of participants during the past year. Among the 504 participants, five with no information on physical activity were excluded from the analysis. Finally, we analyzed 499 participants. Written informed consent was given by each participants. This study received ethical approval from the Kangwon National University Hospital IRB (KNUH 2012-06-007).

2. Measurement

We performed spirometry using an Easy One Kit (NDD, Zurich, Switzerland). All lung function tests were performed as recommended by the American Thoracic Society/European Respiratory Society[18]. We defined COPD as post-bronchodilator forced expiratory volume in 1 second/forced vital capacity (FEV_1/FVC) ratio of <0.7. We assessed physical activity using questionnaires. Participants reported whether they performed regular physical activities until they sweated during the past year (yes/no); accordingly, we categorized the participants into activity and inactivity groups.

In this study, the following demographic and lifestyle factors were included: age, sex, education, marriage status, income, smoking status, and pack-years of cigarette smoking. Dyspnea was assessed using the modified Medical Research Council (mMRC) dyspnea grade. We evaluated health-related quality of life by calculating the total score on the patient-reported COPD Assessment Test (CAT).

3. Statistical analysis

Continuous variables were presented as mean±standard deviation, and categorical variables were presented as frequencies and percentages. The least square means of the lung

function, mMRC scores, and CAT scores based on physical activity were evaluated using a general linear model. The mean of lung function was adjusted for age, sex, smoking status, pack-years of cigarette smoking, and height, whereas the means of the mMRC and CAT scores were adjusted for age, sex, smoking status, and pack-years of cigarette smoking. Furthermore, we performed a stratification analysis for smoking status, COPD, and COPD severity. For classification of COPD severity among COPD patients, we classified as follows: mild, $FEV_1 \geq 80\%$ predicted; moderate, $50\% \leq FEV_1 < 80\%$ predicted; and ≥severe, $FEV_1 < 50\%$ predicted[19].

In this study, all statistical analyses were performed using SAS (version 9.4, SAS Institute Inc., Cary, NC, USA). We considered statistical significance at p<0.05.

Results

Table 1 summarizes the baseline characteristics of the participants. The mean age of the participants was 72 years, and 72% were male. While 43% were former smokers, 20% were current smokers. In addition, the mean pack-year of cigarette smoking of the participants was 17, and the pack-years of cigarette smoking was higher in the inactivity group than the activity group.

Table 2 presents the correlation between lung function and symptoms based on physical activity at baseline. Compared with inactivity group, the mean FEV_1 adjusted for confounding factors was higher in the activity group. The mean FEV_1 was 1.97 and 2.09 L among inactive and active participants, respectively (p=0.03). However, no significant difference in the FVC, CAT scores, and mMRC scores was observed. In the stratification analysis by smoking status, the activity group exhibited higher FEV_1 than that exhibited by the inactivity group among former smokers. The mean FEV_1 of inactive and active participants was 1.97 and 2.18 L, respectively (p=0.02). The activity group exhibited lower FVC than that exhibited by the inactivity group among current smokers. The mean FVC of inactive and active participants was 3.27 and 2.94 L, respectively (p=0.02) (Table 3). We observed no significant difference in the stratification analysis by COPD (Table 4). As a result of stratification analysis by COPD severity, the activity group exhibited a higher FEV_1 than the inactivity group in mild COPD subgroup (Table 5).

Discussion

This study established a correlation between physical activity and FEV_1 in elderly participants from the CODA cohort study. After adjusting for confounding factors, the activity group exhibited higher FEV_1 than that exhibited by the inactivity group. This correlation was observed among former

Table 2. Correlations between the lung function and symptoms and physical activity at the baseline

Physical activity	FEV$_1$ (L)			FVC (L)			CAT score			mMRC score		
	LSmean±SE*	Mean difference	p-value	LSmean±SE*	Mean difference	p-value	LSmean±SE†	Mean difference	p-value	LSmean±SE†	Mean difference	p-value
Inactivity	1.97±0.04	Ref.		3.01±0.05	Ref.		16.47±0.76	Ref.		1.37±0.09	Ref.	
Activity	2.09±0.06	0.12	0.03	3.02±0.07	0.01	0.85	15.76±1.14	−0.71	0.51	1.25±0.13	−0.12	0.34

*Adjusted for age, sex, smoking status, pack-years, and height. †Adjusted for age, sex, smoking status, and pack-years.
FEV$_1$: forced expiratory volume in 1 second; FVC: forced vital capacity; CAT: COPD Assessment Test; mMRC: modified Medical Research Council; LSmean: least square mean; SE: standard error.

Table 3. Correlation between the lung function and symptoms and physical activity at the baseline by the smoking status

	FEV$_1$ (L)			FVC (L)			CAT score			mMRC score		
	LSmean±SE*	Mean difference	p-value	LSmean±SE*	Mean difference	p-value	LSmean±SE†	Mean difference	p-value	LSmean±SE†	Mean difference	p-value
Never (n=187)												
Inactivity	1.84±0.05	Ref.		2.69±0.06	Ref.		16.69±1.19	Ref.		1.43±0.14	Ref.	
Activity	1.95±0.07	0.12	0.12	2.76±0.08	0.07	0.39	15.24±1.73	−1.45	0.43	1.13±0.21	−0.30	0.17
Former (n=212)												
Inactivity	1.97±0.21	Ref.		3.13±0.26	Ref.		17.73±3.74	Ref.		1.71±0.43	Ref.	
Activity	2.18±0.22	0.21	0.02	3.26±0.27	0.13	0.25	17.74±3.98	0.01	0.81	1.75±0.46	0.05	0.99
Current (n=102)												
Inactivity	2.19±0.24	Ref.		3.27±0.30	Ref.		18.51±4.68	Ref.		1.90±0.53	Ref.	
Activity	2.05±0.26	−0.14	0.24	2.94±0.31	−0.33	0.02	17.76±4.94	−0.75	0.74	1.74±0.56	−0.15	0.55

*Adjusted for age, sex, and height. †Adjusted for age and sex.
FEV$_1$: forced expiratory volume in 1 second; FVC: forced vital capacity; CAT: COPD Assessment Test; mMRC: modified Medical Research Council; LSmean: least square mean; SE: standard error.

Table 4. Correlation between the lung function and symptoms and physical activity at the baseline by COPD

	FEV₁ (L)			FVC (L)			CAT score			mMRC score		
	LSmean±SE*	Mean difference	p-value	LSmean±SE*	Mean difference	p-value	LSmean±SE†	Mean difference	p-value	LSmean±SE†	Mean difference	p-value
COPD (n=324)												
Inactivity	1.83±0.05	Ref.		3.06±0.07	Ref.		18.16±0.99	Ref.		1.58±0.12	Ref.	
Activity	1.93±0.07	0.10	0.14	3.09±0.10	0.03	0.76	18.14±1.54	−0.02	0.99	1.52±0.18	−0.05	0.74
Non-COPD (n=175)												
Inactivity	2.25±0.06	Ref.		2.90±0.07	Ref.		13.85±1.31	Ref.		0.98±0.15	Ref.	
Activity	2.25±0.08	0.00	0.92	2.91±0.10	0.01	0.96	13.31±1.73	−0.57	0.75	0.92±0.20	−0.05	0.77

*Adjusted for age, sex, smoking status, pack-years of cigarette smoking, and height. †Adjusted for age, sex, smoking status, and pack-years of cigarette smoking.
COPD: chronic obstructive pulmonary disease; FEV₁: forced expiratory volume in 1 second; FVC: forced vital capacity; CAT: COPD Assessment Test; mMRC: modified Medical Research Council; LSmean: least square mean; SE: standard error.

Table 5. Correlation between lung function and symptoms and physical activity at the baseline by COPD severity

	FEV₁ (L)			FVC (L)			CAT score			mMRC score		
	LSmean±SE*	Mean difference	p-value	LSmean±SE*	Mean difference	p-value	LSmean±SE†	Mean difference	p-value	LSmean±SE†	Mean difference	p-value
Mild (n=162)												
Inactivity	2.13±0.04	Ref.		3.36±0.07	Ref.		16.48±1.40	Ref.		1.33±0.15	Ref.	
Activity	2.25±0.06	0.12	0.02	3.44±0.10	0.08	0.37	17.80±2.00	1.32	0.46	1.49±0.22	0.16	0.41
Moderate (n=135)												
Inactivity	1.65±0.04	Ref.		2.87±0.07	Ref.		19.93±1.59	Ref.		1.87±0.20	Ref.	
Activity	1.71±0.06	0.06	0.21	2.88±0.12	0.01	0.94	20.12±2.73	0.19	0.94	1.65±0.34	−0.22	0.45
≥Severe (n=27)												
Inactivity	0.93±0.08	Ref.		2.07±0.22	Ref.		23.16±2.81	Ref.		1.83±0.38	Ref.	
Activity	0.97±0.10	0.04	0.70	1.86±0.26	−0.21	0.38	21.25±3.72	−1.91	0.57	1.98±0.51	0.15	0.75

*Adjusted for age, sex, smoking status, pack-years, and height. †Adjusted for age, sex, smoking status, and pack-years.
COPD: chronic obstructive pulmonary disease; FEV₁: forced expiratory volume in 1 second; FVC: forced vital capacity; CAT: COPD Assessment Test; mMRC: modified Medical Research Council; LSmean: least square mean; SE: standard error; Mild: FEV₁ ≥80% predicted; Moderate: 50%≤FEV₁ <80% predicted; ≥Severe: FEV₁ <50% predicted.

smokers; however, no such correlation was observed in the stratification analysis by COPD.

Among all the participants, only 23% performed regular physical activity. In Korea, cement plants are located in the rural areas of Kangwon and Chungbuk that have a relatively more aged population. The Korea National Health and Nutrition Examination Survey reported that the percentage of aerobic and muscular physical activity in adults aged >65 years was 34.4% and 15.2%, respectively[20]. In this study, the questionnaire focused on regular physical activities until participants sweated. Only a small proportion in this cohort answered this question affirmatively, perhaps because our study cohort represented a more aged population.

This study corroborates the findings of two prior studies on older adults. In the European Prospective Investigation of Cancer (EPIC)-Norfolk study, FEV_1 was higher with escalating vigorous activity time in adults aged 45–74 years[21]. The English Longitudinal Study of Aging reported a positive correlation between physical activity and lung function in adults with an average age of 63 years[22]. In COPD, which is characterized by low lung function, the quality of life could be decreased because of exacerbation, hospitalization, and mortality[23], which can be reduced due to physical activity[24,25]. In addition, Esteban et al. have reported that among older patients with COPD, those with high levels of physical activity had enhanced health-related quality of life[26]. Despite being insignificant in the COPD subgroup, the current study demonstrated a positive effect of physical activity on lung function in all cohort participants. Of note, a negative result of the subgroup could be attributed to the relatively small sample size. In previous study from elderly COPD patients in Korea, increased dyspnea scale and presence of depression were associated with low-level physical activity[27].

Reportedly, smoking reduces lung function and cardiorespiratory fitness[28,29]. Walters et al.[30] have suggested that smoking accelerates the aging of small airway epithelium at molecular levels. Hence, the stratification analysis by smoking status in this study revealed that regular physical activity correlated with high FEV_1 in former smokers. Prior studies have reported inconsistent results regarding the correlation between physical activity and lung function according to smoking status. Luzak et al.[13] have established a positive correlation between physical activity and lung function among ex-/current smokers, whereas Barboza et al.[31] have reported no such correlation in smokers. In smokers, low-grade systemic inflammatory responses, including C-reactive protein, fibrinogen, interleukin-6, and white blood cells, have been identified, and most have recovered after smoking cessation. Nevertheless, several systemic inflammation markers increased in former smokers after they stopped smoking[32]. A study of adults aged >40 years indicated interactions of smoking and FEV_1 on markers of systemic inflammation[33]. In several studies, the mechanism between physical activity and inflammatory biomarkers remains unclear, although it has been reported that physical activity correlates with low inflammatory biomarkers in elderly adults[34-36]. The present study has reported the positive association between lung function and physical activity in former smokers. In current smokers, these beneficial effects were not observed probably because the smoking effects were very strong. The activity group had higher FEV_1 than inactivity group among mild COPD subgroup. There remain inconsistent reports in beneficial effects of physical activity on quality of life, dyspnea, or long-term disease progression in patients with mild or moderate stage[37].

Our study participants lived near cement plants and were exposed to cement dust. To the best of our knowledge, very few cohort studies have investigated such specific environments. Thus, a strength of this study is the acquisition of valuable and useful data. However, this study had some limitations. First, physical activity may have been underestimated because it was assessed using questionnaires. Therefore, future studies with precise assessment of physical activity are warranted. Second, this study fails to explain the causal relationship between physical activity and lung function owing to its cross-sectional study design, necessitating future analyses with longitudinal changes in lung function.

In conclusion, this study reveals that regular physical activity correlates with FEV_1 in the CODA cohort, and this correlation is most robust in former smokers. Future study will be needed to evaluate the effect of regular activity on lung function in dusty areas.

Authors' Contributions

Conceptualization: Han Y, Kim WJ. Methodology: Kwon SO, Kim WJ. Formal Analysis: Han Y. Data curation: Heo Y, Hong Y. Writing - original draft preparation: Han Y. Writing - review and editing: Heo Y, Hong Y, Kwon SO, Kim WJ. Approval of final manuscript: all authors.

Conflicts of Interest

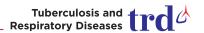No potential conflict of interest relevant to this article was reported.

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