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ORIGINAL RESEARCH

Association Between Urban Green Space and Acute Exacerbations of COPD in Korea: A Nationwide Study Using the NHIS-NSC Cohort

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Background: Chronic obstructive pulmonary disease (COPD) is a major health concern in Korea, with a higher burden of acute exacerbations (AE-COPD) compared to Western populations. Environmental exposures such as smoking and air pollution are known contributors, but the impact of urban green space remains underexplored.

Methods: We conducted a cohort study using the Korean National Health Insurance Service–National Sample Cohort (2006–2019), including 5,171 patients aged ≥40 years with at least two COPD-related prescriptions within one year. Urban green space exposure was defined as the proportion of designated park area to total district area (2017 KOSIS data) and categorized into quartiles. Cox proportional hazards models estimated associations with AE-COPD and all-cause mortality, adjusting for demographic and clinical factors. Subgroup analyses were conducted by age, sex, income, comorbidities, BMI, smoking, and physical activity.

Results: Among 5,171 COPD patients (mean age, 67.5 years; 60.7% male), 1,431 AE-COPD events occurred over 40,486 person-years. AE-COPD incidence declined from 35.4 to 31.3 per 1,000 person-years across green space quartiles. Compared to the lowest quartile, the highest quartile showed a lower AE-COPD risk (adjusted hazard ratio [aHR], 0.75; 95% CI, 0.58–0.96; p for trend = 0.016). Stronger trends were observed in younger adults, men, high-income individuals, and those with comorbidities, though interaction tests were not significant. In a health screening subgroup (n = 3,318), patterns were consistent. No significant association was found with all-cause mortality.

Conclusion: Greater urban green space coverage may be associated with reduced AE-COPD risk. However, results should be interpreted with cautiously given model limitations and exploratory nature of subgroup findings.

Keywords: chronic obstructive pulmonary disease, urban green space, acute exacerbation, cohort study, Korea

Introduction

Chronic obstructive pulmonary disease (COPD) is a heterogeneous lung disorder characterized by chronic respiratory symptoms resulting from airway and/or alveolar abnormalities that lead to progressive airflow limitation. It is a major global health concern associated with significant mortality and socioeconomic burden[1] Acute exacerbations of COPD (AE-COPD) contribute substantially to COPD-related deaths, underscoring the need to identify factors that influence these events.

In Korea, a recent study from the Korea COPD Subgroup Study (KOCOSS) cohort reported a mean of 1.1 moderate or severe AE-COPD events per patient year—substantially higher than rates observed in Western populations—indicating a high exacerbation burden. The study also highlighted environmental exposures such as tobacco smoking, air pollution, and biomass fuel as important contributors to increased exacerbation risk and disease progression.[2] While smoking remains a major cause

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of COPD, recent research increasingly emphasizes the role of environmental[3] and occupational exposures, including fine particulate matter, biomass smoke, and dust – as drivers of both COPD incidence and exacerbations.[4–6]

Urban green space, a proxy for natural vegetation within residential areas, has received growing attention as a modifiable environmental factor associated with improved respiratory health. A mechanism underlying this association is the potential of urban green spaces to improve air quality by reducing air pollution (ie, PM2.5).[7,8] Several previous studies have revealed that urban green spaces, compared to rural areas, have more distinctly defined vegetation zones and can improve air quality more efficiently, even at small scales of urban districts.[9–11] Although some studies suggest that exposure to green space may reduce the risk of cardiovascular disease, mental health disorders, and obesity, our focus is on its relevance to respiratory outcomes, particularly COPD. Prior research has linked green space to improved air quality, physical activity, and microbial diversity, all of which may influence respiratory health.[12] Recent epidemiologic evidence from the United States,[13] United Kingdom,[14] Belgium,[15] and other has reported inverse associations between green space exposure and all-cause mortality, including among individuals with COPD. In South Korea, studies have linked green space exposure to reduced mortality from cardiovascular,[14] allergic,[16,17] and renal disease.[18]

However, research in Asia has primarily focused on the relationship between green space and COPD incidence rather than acute exacerbations. For example, residential green space in China has been associated with lower COPD prevalence,[19] and a recent study in Chongqing suggested regional variation in COPD-related mortality risk.[20] Despite AE-COPD being a key driver of morbidity, mortality, and healthcare burden, no study to date has specifically examined its relationship with urban green space in the Asian context, highlighting a critical gap in the literature.

To address this gap, we analyzed data from the Korean National Health Insurance Service–National Sample Cohort (NHIS-NSC) from 2006 to 2019 to investigate the association between residential green space exposure and AE-COPD and all-cause mortality in patients with COPD. Green space exposure was assessed using 2017 park area data from the Korean Statistical Information Service (KOSIS), which reflects the proportion of designated park area within each district. We hypothesized that higher exposure to urban green space would be associated with a lower risk of AE-COPD and mortality.

Methods

Data Source

This study utilized data from the Korean National Health Insurance Service–National Sample Cohort (NHIS-NSC), covering the period from 2006 to 2019 (NHIS No.: NHIS-2023-2-302). The NHIS-NSC includes 2% of the eligible Korean population in 2006, sampled via stratification based on sex, age, insurance type, premium decile, and region.[21] It provides comprehensive, longitudinal data on healthcare utilization and demographic characteristics. Residential addresses are updated annually at the district (Gu) level.[22] To protect personal information, all data were de-identified and sensitive variables were masked or grouped.

Study Population

We identified patients with COPD aged ≥40 years who had both a diagnosis of COPD (ICD-10: J43, excluding J43.0 [MacLeod syndrome], or J44) and a prescription for COPD-related medications between January 1, 2006, and December 31, 2015. To ensure chronicity, patients were required to have at least one additional COPD diagnosis and related prescription within the following year (Figure 1). COPD-related medications included long-acting muscarinic antagonists (LAMAs), long-acting beta-2 agonists (LABAs), inhaled corticosteroids (ICSs), ICS/LABA combinations, short-acting bronchodilators (SAMAs/SABAs), methylxanthines, oral corticosteroids, and systemic beta-2 agonists (Supplementary Table 1).[23]

The date of the first qualifying diagnosis was set as the index date. To reduce immortal time bias and allow sufficient follow-up, only patients diagnosed through 2015 were included. The interval between first and second prescriptions was examined, and sensitivity analyses were performed excluding individuals with more than 180 days between them. The analysis was restricted to residents of the seven largest metropolitan cities in Korea (Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan), which allow stratification based on urban green space levels and ensure consistent exposure classification.

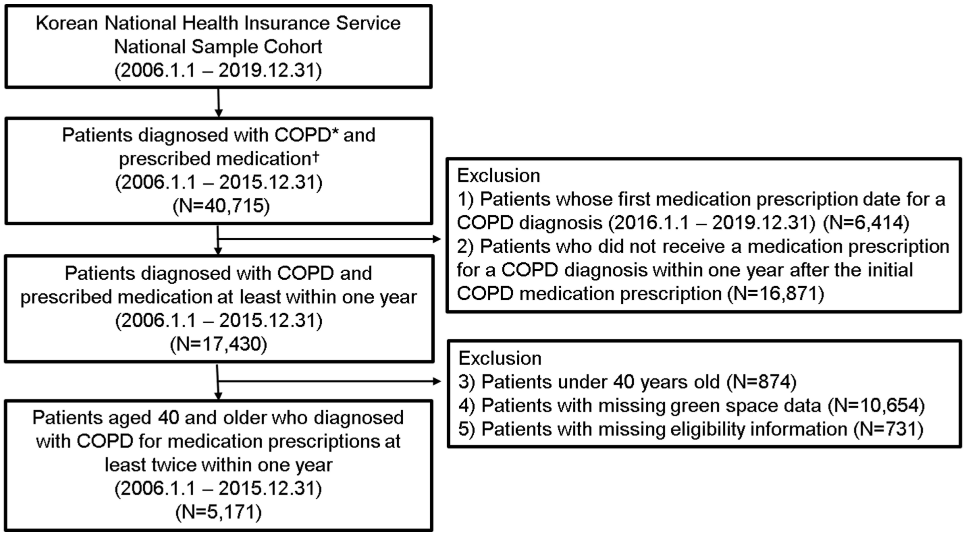

Figure 1 Flowchart of the study population selection from the Korean National Health Insurance Service–National Sample Cohort (2006.1.1–2019.12.31).

Notes: Inclusion criteria included patients diagnosed with COPD and prescribed medication between 2006 and 2015. Exclusion criteria were applied sequentially to patients with delayed prescription (after 2016), those without follow-up prescriptions within one year, patients under 40 years old, and those with missing green space or eligibility data. *COPD diagnosis: ICD-10 codes J43–J44, excluding J43.0. †COPD medications include LAMA, LABA, ICS, ICS/LABA, SAMA, SABA, methylxanthines, oral corticosteroids, and systemic beta-2 agonists.

Abbreviations: COPD, chronic obstructive pulmonary disease.

Exposure Assessment: Urban Green Space

Urban green space was assessed using park area data from the Korean Statistical Information Service (KOSIS), based on a 2017 nationwide survey conducted by the Ministry of Land, Infrastructure, and Transport (MOLIT). This dataset includes multiple park types: urban natural parks (including national urban parks), neighborhood parks, children's parks, historic and cultural parks, waterside parks, cemetery parks, sports parks, agricultural parks, and other public parks designated by local ordinances.[24]

For each district, we calculated the total park area (m²) and derived a park-area-based greenness index, defined as the ratio of total park area to total district area.[25] Although the park data represent a single year (2017), we applied the same static measure across the entire study period (2006–2019), based on the assumption that relative green space rankings among districts remained generally stable Potential limitations due to urban development and changes in green space availability over time are acknowledged. The resulting index was categorized into quartiles: quartile 1 (Q1; lowest greenness), quartile 2 (Q2), quartile 3 (Q3), and quartile 4 (Q4; high greenness) (Figure 2).

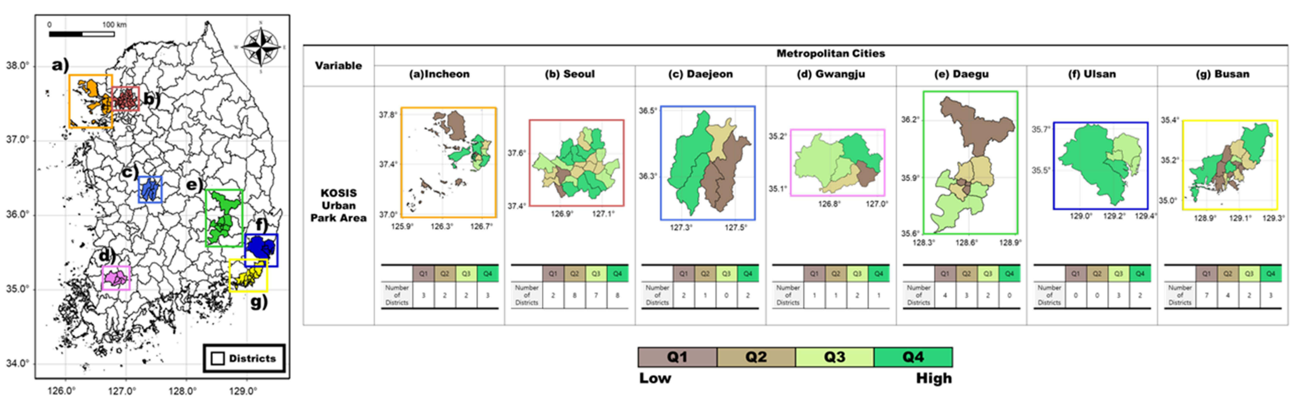

Figure 2 Regional distribution of green space exposure across selected districts in South Korea.

Notes: The main map displays the national administrative boundaries, with selected regions indicated by colored boxes corresponding to subpanels a–g. (**a**) Incheon Metropolitan City, (**b**) Seoul Special Metropolitan City, (**c**) Daejeon Metropolitan City, (**d**) Gwangju Metropolitan City, (**e**) Daegu Metropolitan City, (**f**) Ulsan Metropolitan City, (**g**) Busan Metropolitan City. Districts are classified by quartiles based on the average urban park area per capita derived from the Korean Statistical Information Service (KOSIS) database: Q1 (lowest greenness) to Q4 (highest greenness).

Outcomes

The primary outcome was the first occurrence of acute exacerbation of COPD (AE-COPD), defined as a prescription for systemic corticosteroids and/or antibiotics within 7 days of a healthcare visit (outpatient, emergency department, or hospitalization) with a COPD diagnosis.[23] This operational definition may not fully distinguish mild from severe events and could include some prophylactic treatments; this is discussed as a limitation. The secondary outcome was all-cause mortality, determined through NHIS eligibility records. Follow-up continued from the index date until the occurrence of an outcome, death, or end of the study period.

Statistical Analysis

Baseline characteristics were presented as frequencies and proportions for categorical variables and as means with standard deviations (SDs) for continuous variables. Cox proportional hazards regression analysis was employed to estimate adjusted hazard ratios (aHRs) and their corresponding 95% confidence intervals (CIs), accounting for time-to-event data through the hazard function.[26] The proportional hazards assumption was assessed using Schoenfeld residuals. The models were adjusted for variables with a p-value ≤ 0.2 in the baseline characteristics analysis or those considered clinically important, including sex, age, income (insurance premium quartiles), disability status (normal, mild, severe), and the Charlson Comorbidity Index (CCI).[27] The CCI, calculated from diagnoses within one year before the index date, included a range of chronic conditions excluding COPD (eg, cardiovascular disease, diabetes, liver disease, cancer, HIV).[28]

The green space index was modeled in quartiles, with Q1 as the reference. Trend tests were conducted by treating quartiles as continuous variables to assess linear exposure-response relationships.[29] This approach was supported by preliminary visual inspections of exposure-response plots. Subgroup analyses were conducted by sex, age group, income level, and CCI score. For the health screening subgroup, analyses were further stratified by body mass index (BMI, ≤25 or >25 kg/m²), smoking status (never, former, current), and physical activity (≥3 times/week, 1–2 times/week, none). To account for the risk of false-positive findings due to multiple comparisons, subgroup results were interpreted as exploratory, and interaction terms were tested when appropriate. All statistical analyses were performed using SAS Enterprise Guide (version 8.3; SAS Institute Inc., Cary, NC, USA), with significance defined as a two-sided p-value <0.05.

Results

Among the total NHIS-NSC cohort of one million individuals (2006–2015), 34,301 patients were diagnosed with COPD and received at least one prescription for COPD-related medication. Of these, 17,430 received a re-prescription within one year, and a final study population of 5,171 patients aged ≥40 years with at least two prescriptions within a one-year period was identified (Figure 1).

The mean age was 67.5 years (SD, 11.2), with 75.8% aged ≥60 years and 60.7% being male. Income distribution and disability status were relatively even across quartiles, and no significant differences were observed in baseline characteristics (Table 1).

In the multivariable analysis adjusted for all covariates, a significant inverse association was observed between urban green space coverage and the risk of AE-COPD (p for trend = 0.016). Specifically, patients residing in areas with the highest green space coverage (fourth quartile) had a significantly lower risk of AE-COPD (HR, 0.75; 95% CI, 0.58–0.96) compared to those in the lowest quartile. The incidence rate of AE-COPD progressively decreased across quartiles, from 35.37 per 1,000 person-years (95% CI, 32.97–37.86) in the first quartile to 31.33 (95% CI, 29.48–33.25) in the fourth quartile. However, increased green space coverage was not associated with a statistically significant reduction in all-cause mortality (p for trend = 0.738). The incidence rates of all-cause death remained relatively consistent across quartiles (Table 2).

Stratified analyses suggested possible variation in the association between green space and AE-COPD risk across subgroups. In particular, lower risks in the highest green space quartile were observed among individuals aged 40–49 years (aHR, 0.12; 95% CI, 0.02–0.65; p for trend = 0.048), men (aHR, 0.70; 95% CI, 0.52–0.95; p for trend = 0.053), and those in the upper half of income distribution (aHR, 0.53; 95% CI, 0.37–0.76; p for trend = 0.007). A protective pattern

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Table 1 Descriptive Characteristics of Study Population

Characteristic N, (%)	Total	Urban Green Space Coverage				P value
		First Quartile (low)	Second Quartile	Third Quartile	Fourth Quartile (high)	
Urban green space coverage, mean (SD), %	3.110 (2.733)	0.437 (0.294)	1.571 (0.326)	3.410 (0.663)	6.815 (2.276)	
Urban green space coverage, median (IQR)	2.45 (3.56)	0.5 (0.53)	1.54 (0.56)	3.47 (0.84)	6.15 (2.25)	
Participants	5171 (100)	1032 (19.96)	1472 (28.47)	1261 (24.39)	1406 (27.19)	
Age, years, (SD)	67.52 (11.16)	67.57 (10.78)	67.16 (11.10)	67.57 (11.53)	67.83 (11.15)	
40-49	363 (7.02)	58 (5.62)	109 (7.4)	101 (8.01)	95 (6.76)	0.1231
50-59	889 (17.19)	190 (18.41)	270 (18.34)	206 (16.34)	223 (15.86)	
≥ 60	3919 (75.79)	784 (75.97)	1093 (74.25)	954 (75.65)	1088 (77.38)	
Sex, Male	3136 (60.65)	631 (61.14)	893 (60.67)	758 (60.11)	854 (60.74)	0.9667
Income						0.1308
First quartile (highest)	959 (18.55)	157 (15.21)	271 (18.41)	257 (20.38)	274 (19.49)	
Second quartile	1398 (27.04)	285 (27.62)	381 (25.88)	347 (27.52)	385 (27.38)	
Third quartile	1327 (25.66)	278 (26.94)	388 (26.36)	308 (24.43)	353 (25.11)	
Fourth quartile (lowest)	1487 (28.76)	312 (30.23)	432 (29.35)	349 (27.68)	394 (28.02)	
Disability						0.2756
Serious	289 (5.59)	47 (4.55)	71 (4.82)	89 (7.06)	82 (5.83)	
Mild	434 (8.39)	87 (8.43)	118 (8.02)	109 (8.64)	120 (8.53)	
Normal	4448 (86.02)	898 (87.02)	1283 (87.16)	1063 (84.30)	1204 (85.63)	
Charlson comorbidity index						0.0737
0	362 (7)	90 (8.72)	110 (7.47)	75 (5.95)	87 (6.19)	
1	1334 (25.80)	280 (27.13)	362 (24.59)	328 (26.01)	364 (25.89)	
≥2	3475 (67.20)	662 (64.15)	1000 (67.93)	858 (68.04)	955 (67.92)	

Notes: Data are presented as the number (%), unless otherwise indicated. P values are based on the chi-square test.

Table 2 Association of Urban Green Space Coverage with the Risk of AE-COPD and Death of COPD Patients

COPD	Urban green space coverage				
	First Quartile (Low)	Second Quartile	Third Quartile	Fourth Quartile (High)	p for Trend
Total, n=5171	1032	1472	1261	1406	
AE COPD					
Events	804 (77.91)	1139 (77.38)	966 (76.61)	1061 (75.46)	
Person-years	2273.2	3261.9	2919.7	3386.1	
Incidence Rate (95% CI)	35.37 (32.97–37.86)	34.92 (32.92–36.97)	33.09 (31.03–35.2)	31.33 (29.48–33.25)	
aHR (95% CI)	1.00 (Reference)	1.04 (0.82–1.33)	1.00 (0.79–1.28)	0.75 (0.58–0.96)	0.016
All cause death					
Events	357 (34.59)	515 (34.99)	462 (36.64)	497 (35.35)	
Person-years	1494.3	2067.7	1954.0	2061.8	
Incidence Rate (95% CI)	23.89 (21.48–26.43)	24.91 (22.8–27.1)	23.64 (21.54–25.85)	24.11 (22.03–26.27)	
aHR (95% CI)	1.00 (Reference)	1.09 (0.76–1.56)	0.94 (0.66–1.33)	0.96 (0.67–1.37)	0.738

Notes: Data are presented as the number (%), unless otherwise indicated. Adjusted for age, sex, income, disability and Charlson comorbidity index (CCI). P for trend calculated by treating the quartile variable of the green space index as a continuous variable in the Cox proportional hazards models.

was also observed in patients with comorbidities (CCI ≥1; aHR, 0.72; 95% CI, 0.56–0.93; p for trend = 0.014). Nonetheless, none of the interaction terms reached statistical significance (all p for interaction > 0.05), and these subgroup-specific findings should be interpreted as exploratory rather than confirmatory (Table 3).

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Table 3 Stratified Analysis on the Association of Urban Green Space Coverage with Risk of AE-COPD (n=5171)

		Urban Green Space Coverage					
		First Quartile (Low)	Second Quartile	Third Quartile	Fourth Quartile (High)	p for Trend	p for Interaction
Age	aHR (95% CI)						
	40–49	1.00 (Reference)	0.58(0.11–3.21)	0.20(0.03–1.24)	0.12(0.02–0.65)	0.048	
	50–59	1.00 (Reference)	1.27(0.64–2.52)	0.78(0.38–1.59)	0.58(0.29–1.15)	0.167	
	≥60	1.00 (Reference)	1.03(0.78–1.35)	1.07(0.82–1.40)	0.79(0.60–1.04)	0.075	0.064
Sex	aHR (95% CI)						
	Men	1.00 (Reference)	0.94(0.69–1.28)	0.97(0.72–1.32)	0.70(0.52–0.95)	0.053	
	Women	1.00 (Reference)	1.28(0.84–1.95)	1.13(0.74–1.72)	0.86(0.55–1.33)	0.225	0.818
Income	aHR (95% CI)						
	Upper half	1.00 (Reference)	0.72(0.50–1.04)	0.73(0.52–1.04)	0.53(0.37–0.76)	0.007	
	Lower half	1.00 (Reference)	1.39(0.99–1.95)	1.26(0.89–1.77)	0.99(0.70–1.39)	0.079	0.869
CCI	aHR (95% CI)						
	0	1.00 (Reference)	2.33(0.58–9.32)	1.57(0.37–6.66)	1.62(0.45–5.80)	0.691	
	≥1	1.00 (Reference)	0.98(0.76–1.27)	0.99(0.77–1.27)	0.72(0.56–0.93)	0.014	0.768

Notes: Data are presented as the number (%), unless otherwise indicated. Adjusted for age, sex, health insurance premium, disability and Charlson comorbidity index. P for trend calculated by treating the quartile variable of the green space index as a continuous variable in the Cox proportional hazards models.

In supplementary analyses restricted to 3,318 individuals who underwent standardized health screening examinations, baseline characteristics remained balanced across green space exposure quartiles. Most participants were aged ≥60 years (75.9%), and 61.1% were male. Comorbidity burden was substantial, with 67.5% having a Charlson Comorbidity Index (CCI) score ≥2. Distributions of income, disability status, smoking behavior, and physical activity levels did not significantly differ across quartiles (Supplementary Table 2).

Within this subgroup, the inverse association between green space and AE-COPD was generally consistent. Reduced AE-COPD risks in the highest green space quartile were observed among patients aged 40–49 years (aHR, 0.00; 95% CI, 0.00–0.05), ≥60 years (aHR, 0.71; 95% CI, 0.51–0.99), men (aHR, 0.67; 95% CI, 0.46–0.99), high-income individuals (aHR, 0.45; 95% CI, 0.28–0.71), those with CCI ≥1 (aHR, 0.67; 95% CI, 0.49–0.93), BMI ≤25 (aHR, 0.58; 95% CI, 0.39–0.85), and individuals engaging in physical activity ≥3 times per week (p for trend = 0.022) (Table 4). However,

Table 4 Stratified Analysis on the Association of Urban Green Space Coverage with Risk of AE-COPD Among COPD Patients Who Underwent Health Screening Examinations (n=3318)

		Urban Green Space Coverage					
		First Quartile (Low)	Second Quartile	Third Quartile	Fourth Quartile (High)	p for Trend	p for Interaction
Age	aHR (95% CI)						
	40–49	1.00 (Reference)	0.16 (0.00–29.86)	0.06 (0.00–15.86)	0.00 (0.00–0.05)	0.026	
	50–59	1.00 (Reference)	2.18 (0.61–7.82)	1.47 (0.34–6.45)	0.56 (0.20–1.63)	0.179	
	≥60	1.00 (Reference)	1.06 (0.76–1.49)	1.10 (0.79–1.54)	0.71 (0.51–0.99)	0.019	0.484
Sex	aHR (95% CI)						
	Men	1.00 (Reference)	1.01 (0.68–1.49)	1.02 (0.69–1.49)	0.67 (0.46–0.99)	0.050	
	Women	1.00 (Reference)	1.26 (0.74–2.14)	1.06 (0.62–1.83)	0.67 (0.38–1.16)	0.075	0.731
Income	aHR (95% CI)						
	Upper half	1.00 (Reference)	0.74 (0.46–1.18)	0.69 (0.44–1.09)	0.45 (0.28–0.71)	0.050	
	Lower half	1.00 (Reference)	1.37 (0.89–2.09)	1.35 (0.87–2.08)	0.93 (0.61–1.43)	0.075	0.443
CCI	aHR (95% CI)						
	0	1.00 (Reference)	0.01 (0.00–36.58)	0.06 (0.00–97.87)	N/A	0.667	
	≥1	1.00 (Reference)	1.04 (0.76–1.42)	1.02 (0.75–1.40)	0.67 (0.49–0.93)	0.007	0.509

(*Continued*)

Table 4 (Continued).

		Urban Green Space Coverage					
		First Quartile (Low)	Second Quartile	Third Quartile	Fourth Quartile (High)	p for Trend	p for Interaction
Disability							
	Serious	1.00 (Reference)	1.93 (1.06–3.52)	2.25 (1.22–4.16)	1.06 (0.57–1.97)	0.003	
	Mild	1.00 (Reference)	0.86 (0.58–1.26)	0.71 (0.49–1.04)	0.57 (0.39–0.84)	0.022	
	Normal	1.00 (Reference)	0.95 (0.84–1.07)	0.94 (0.83–1.06)	1 (0.88–1.13)	0.638	0.082
Body mass index, kg/m2							
	≤ 25	1.00 (Reference)	1.01 (0.69–1.47)	0.97 (0.65–1.44)	0.58 (0.39–0.85)	0.003	
	> 25	1.00 (Reference)	1.22 (0.7–2.14)	1.25 (0.73–2.13)	0.89 (0.51–1.55)	0.500	0.686
Smoking							
	Never smoker	1.00 (Reference)	1.15 (0.76–1.74)	1.19 (0.78–1.8)	0.73 (0.48–1.12)	0.047	
	Former smoker	1.00 (Reference)	8.55 (1.64–44.64)	2.05 (0.58–7.3)	1.66 (0.35–7.75)	0.025	
	Current smoker	1.00 (Reference)	0.74 (0.43–1.27)	0.74 (0.42–1.29)	0.52 (0.31–0.89)	0.114	0.638
Physical activity							
	Non exercise	1.00 (Reference)	1.13 (0.55–2.36)	0.68 (0.33–1.4)	0.98 (0.48–2.02)	0.479	
	Once or twice a week	1.00 (Reference)	1 (0.61–1.65)	1.02 (0.62–1.67)	0.65 (0.39–1.08)	0.123	
	At least three times a week	1.00 (Reference)	1.21 (0.72–2.05)	1.26 (0.75–2.11)	0.63 (0.37–1.07)	0.022	0.401

Notes: Adjusted for age, sex, income, disability, Charlson comorbidity index, disability, BMI, smoking and physical activity. P for trend calculated by treating the quartile variable of the green space index as a continuous variable in the Cox proportional hazards models.

Table 5 Association of Urban Green Space Coverage with the Risk of AE-COPD and Death Among People Who Underwent Health Screening Examinations (n=3318)

COPD	Urban Green Space Coverage				
	First Quartile (Low)	Second Quartile	Third Quartile	Fourth Quartile (High)	p for Trend
Total, n	672	975	814	857	
AE-COPD					
Events	522 (77.68)	745 (76.41)	621 (76.29)	647 (75.50)	
Person-years	1550.2	2312.5	1960.8	2069.9	
Incidence Rate (95% CI)	33.67(30.85–36.62)	32.22(29.94–34.57)	31.67(29.23–34.21)	31.26(28.89–33.71)	
aHR (95% CI)	1.00 (Reference)	1.06(0.78–1.45)	1.01(0.74–1.38)	0.68(0.50–0.94)	0.007
All cause death					
Events	206 (30.65)	298 (30.56)	260 (31.94)	269 (31.39)	
Person-years	890.5	1218.4	1141.0	1173.7	
Incidence Rate (95% CI)	23.13(20.08–26.4)	24.46(21.76–27.31)	22.79(20.1–25.64)	22.92(20.26–25.74)	
aHR (95% CI)	1.00 (Reference)	1.13(0.70–1.81)	0.90(0.56–1.46)	0.90(0.56–1.44)	0.629

Notes: Data are presented as the number (%), unless otherwise indicated. Adjusted for age, sex, income, disability, Charlson comorbidity index, BMI, smoking and physical activity. P for trend calculated by treating the quartile variable of the green space index as a continuous variable in the Cox proportional hazards models.

tests for statistical interaction remained nonsignificant across all subgroups (all p for interaction > 0.05), and thus these variations should be considered exploratory in nature.

In the overall subgroup, green space coverage remained significantly associated with reduced AE-COPD risk (aHR, 0.68; 95% CI, 0.50–0.94; p for trend = 0.007), although this finding should also be interpreted with caution in light of the model limitations. No significant relationship was found with all-cause mortality (p for trend = 0.629) (Table 5).

Discussion

In this nationwide cohort study, we observed a potential association between greater exposure to urban green space and a reduced risk of acute exacerbation of COPD (AE-COPD). A decreasing trend in AE-COPD incidence was observed across quartiles of green space coverage. While the inverse association appeared stronger in certain subgroups—such as younger adults (40–49 years), men, individuals in the upper income brackets, and those with comorbidities—none of the interaction terms reached statistical significance, suggesting that these subgroup findings should be interpreted as exploratory rather than confirmatory.

Although the association was statistically significant, the absolute difference in AE-COPD incidence between the lowest and highest quartiles was modest (35.4 vs 31.3 per 1,000 person-years), highlighting the need to interpret relative risk reductions within the context of public health impact. In contrast, no significant association was found between green space and all-cause mortality. This null finding may reflect insufficient statistical power, exposure misclassification, or the heterogenous nature of causes contributing to mortality in COPD populations.

Our results are broadly consistent with some prior studies suggesting a potential role of green space on respiratory health, although findings across the literature remain mixed. Such variation likely reflects differences in study setting, population characteristics, and exposure measurement methods. In the Korean context, compact and high-density urban environments may offer relatively equitable access to public green spaces, which may differ from more car-dependent cities. We used district-level park area data from the 2017 Korean Statistical Information Service (KOSIS), which may provide better spatial resolution than remote-sensing-based greenness indices.[30] However, because this static measure was applied uniformly across 2006–2019 study period, temporal changes in green space availability were not captured. This may have introduced exposure misclassification, potentially diluting observed associations. While these findings are consistent with the hypothesis that green space may influence respiratory health through mechanisms such as air pollution reduction or increased physical activity—both of which are known to support lung function. Although some studies have reported protective effects of green space on mortality,[14,15] results remain inconsistent.[31]

Interestingly, inverse associations between green space and AE-COPD appeared stronger among men and individuals with higher income—groups that may differ in health behaviors, disease severity, or access to green space and healthcare. These patterns align with the higher COPD prevalence observed among Korean men, who may therefore experience more measurable environmental benefit.[32,33] However, this contrasts with some studies reporting stronger protective effects among women.[34] One possible explanation is that Korean women with COPD tend to have greater comorbidity burdens and more severe phenotypes,[35,36] which may attenuate their responsiveness to environmental exposures. Similarly, stronger associations among higher-income individuals may reflect differential access to high-quality green space or healthcare services,[14,37] although residual confounding cannot be ruled out. In contrast, no meaningful association was observed among individuals without comorbidities (CCI = 0), suggesting that green space may confer greater respiratory benefits to individuals with underlying health vulnerabilities.

Subgroup analyses in the health screening population generally aligned with the main findings. Stronger inverse associations were observed among individuals with lower BMI, greater physical activity, and mild disabilities—groups potentially more sensitive to environmental influences. However, several estimates were based on small numbers of AE-COPD events, particularly in younger age groups (eg, aHR = 0.00 in 40–49 years), raising concerns about statistical imprecision. These results reinforce the exploratory nature of subgroup analyses and highlight the need for cautious interpretation.

This study has several strengths, including the use of a large, nationally representative cohort; long-term follow-up; and a validated claims-based definition of AE-COPD. Quartiles of green space were treated as continuous variables in trend analyses following visual confirmation of linearity, which enhanced the interpretability of exposure–response patterns.

Nonetheless, several limitations should be acknowledged. First, district-level park area may not accurately reflect individual-level exposure due to within-district heterogeneity and the use of static 2017 data over a long follow-up period. Second, the absence of air pollution and smoking data in the full cohort raises the possibility of residual confounding. Third, reliance on administrative claims data may have led to misclassification of AE-COPD events, particularly in distinguishing between mild and severe exacerbations. Fourth, although stratified analyses by age, sex, income level, CCI, and disability revealed some variation in trends, none of the interaction terms were statistically significant; subgroup findings should thus be interpreted as exploratory, emphasizing within-group trends rather than between-group comparisons. Fifth, other environmental factors affecting air quality—such as proximity to industrial complexes, prevailing wind directions, and geographic location—were not considered due to data limitations, potentially resulting in incomplete adjustment for spatial variation in air pollution.[38, 39] Lastly, in the AE-COPD model, although main exposure variable — urban green space —satisfied the proportionality assumption, two covariates, age and disability status, did not. This violation suggests potential time-varying effects of these two covariates, warranting cautious interpretation of the results.

Conclusion

In this nationwide cohort study, we observed a potential association between greater exposure to urban green space and a reduced risk of acute exacerbation in COPD patients. This inverse association appeared more pronounced in certain subgroups—including younger adults, men, individuals with higher income, and those with comorbid conditions or healthier lifestyles—suggesting that the potential health effects of green space may vary across populations. However, the modest absolute risk reduction, lack of association with all-cause mortality, and absence of statistically significant interaction effects across subgroups indicate that these findings should be interpreted with caution. In particular, given that the AE-COPD model violated the proportional hazards assumption for age and disability status, this limitation should be considered when evaluating the robustness of the results. While our findings support the plausibility of environmental influences on respiratory health, they do not establish causality. Future studies incorporating time-varying and individual-level exposure metrics, direct air quality assessments, and prospective or interventional designs are needed to clarify underlying mechanisms and confirm these associations.

Human Ethics Approval and Declaration

The study protocol was approved by the Ethical Committee of Chung-Ang University Hospital (IRB No. 2307-015-19480) and was conducted in accordance with the approved guidelines. The need for informed consent was waived by the IRB because of the retrospective nature of the study. All data used in this study were fully anonymized prior to access and analysis, and the study complied with relevant data protection and privacy regulations, including the Personal Information Protection Act of the Republic of Korea.

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Disclosure

The authors report no conflicts of interest in this work.

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