Original article

Exposure to air pollution and self-reported depression, anxiety, and stress in chronic respiratory patients: a preliminary study in the urban area of Thailand

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Abstract

Objective: To investigate the association between annual air pollution exposure and mental health problems among patients with chronic respiratory conditions.

Methods: Data were collected among patients with asthma, COPD, rhinitis, and bronchiectasis, who enrolled at the pulmonary and critical care unit of King Chulalongkorn Memorial Hospital, Bangkok. A self-reported questionnaire included sociodemographics and the 21-item Depression Anxiety Stress Scales (DASS-21). A high-resolution spatiotemporal model estimated annual exposure to carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM_{10} and $PM_{2.5}$) at the participants' residences by using the ordinary kriging method. Multivariate logistic regressions were conducted to determine possible associations using a priori selected covariates in the adjusted models.

Results: A total of 98 participants completed the questionnaire. The prevalence of depression, anxiety, and stress among the participants were 30.6%, 28.6%, and 26.5%, respectively. Long-term exposure to CO, O_3, NO_2, SO_2, PM_{10}, and $PM_{2.5}$ averaged 0.9 ppm, 21.4 ppb, 18.2 ppb, 2.6 ppb, 41.0 μg/m^3, and 22.6 μg/m^3, respectively. After controlling for covariates, an increment in annual $PM_{2.5}$ exposure was associated with higher odds of self-reported depression (AOR = 1.34, 95% CI = 1.02 - 1.79).

Conclusion: Long-term exposure to $PM_{2.5}$ is linked to a higher risk of depression among chronic respiratory patients. The finding suggests that policies aiming at lowering air pollution levels could also lower the risk of mental health issues among this population.

Keywords: air pollution, depression, anxiety, stress, respiratory patient

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นิพนธ์ต้นฉบับ

การรับสัมผัสมลพิษอากาศกับภาวะซึมเศร้า ความวิตกกังวล และความเครียด ของผู้ป่วยโรคระบบทางเดินหายใจเรื้อรัง : การศึกษาเบื้องต้น ในพื้นที่เขตเมือง ประเทศไทย

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บทคัดย่อ

วัตถุประสงค์ : เพื่อศึกษาความสัมพันธ์ระหว่างการเผชิญกับมลพิษทางอากาศกับภาวะซึมเศร้า ความวิตกกังวล และความเครียดในผู้ป่วยโรคทางเดินหายใจเรื้อรัง

วิธีการ : เก็บข้อมูลจากผู้ป่วยโรคทางเดินหายใจเรื้อรัง ได้แก่ โรคหอบหืด โรคปอดอุดกั้นเรื้อรัง โรคโพรงจมูกอักเสบเรื้อรังและโรงหลอดลมโป่งพอง ณ โรงพยาบาลจุฬาลงกรณ์ แบบสอบถามประกอบด้วยลักษณะทางสังคมและประชากรและแบบวัดภาวะซึมเศร้า ความวิตกกังวล และความเครียด ฉบับ 21 ข้อ ประมาณค่ามลพิษทางอากาศบริเวณที่อยู่อาศัยของกลุ่มตัวอย่างในช่วงปีก่อนหน้า ได้แก่ CO, O_3, NO_2, SO_2, PM_{10} และ $PM_{2.5}$ โดยวิธีการ ordinary kriging และวิเคราะห์ความสัมพันธ์ระหว่างระดับการสัมผัสมลพิษทางอากาศกับปัญหาสุขภาพจิตด้วย multivariate logistic regression

ผล : กลุ่มตัวอย่าง 98 คน มีความชุกของภาวะซึมเศร้า ความวิตกกังวล และความเครียดเท่ากับร้อยละ 30.6, 28.6 และ 26.5 ตามลำดับ ระดับ CO, O_3, NO_2, SO_2, PM_{10} และ $PM_{2.5}$ บริเวณที่อยู่อาศัยของกลุ่มตัวอย่างมีค่าเฉลี่ยเท่ากับ 0.9 ppm, 21.4 ppb, 18.2 ppb, 2.6 ppb, 41.0 $\mu g/m^3$ และ 22.6 $\mu g/m^3$ ตามลำดับ ระดับ $PM_{2.5}$ ที่เพิ่มสูงขึ้นมีความสัมพันธ์กับการเพิ่มโอกาสการเกิดภาวะซึมเศร้าอย่างมีนัยสำคัญ (AOR = 1.34, 95% CI = 1.02 - 1.79)

สรุป : การเผชิญกับฝุ่นพิษ $PM_{2.5}$ ระยะยาวมีความสัมพันธ์กับความเสี่ยงที่เพิ่มขึ้นของภาวะซึมเศร้าในผู้ป่วยโรคทางเดินหายใจ การลดการเผชิญมลพิษทางอากาศอาจช่วยลดความเสี่ยงภาวะซึมเศร้าในผู้ป่วยทางเดินหายใจ

คำสำคัญ : มลพิษทางอากาศ, ภาวะซึมเศร้า, ความวิตกกังวล, ความเครียด, ผู้ป่วยโรคทางเดินหายใจ

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Previous Knowledge: Previous research suggested a connection between air pollution and mental health, providing a basis for exploring the effects of annual exposure on depression, anxiety, and stress in chronic respiratory patients.

New Knowledge: Long-term exposure to $PM_{2.5}$ is associated with a higher risk of depression, highlighting the importance of targeted interventions to reduce air pollution and address mental health in this group.

Applications: Reducing $PM_{2.5}$ exposure could alleviate mental health issues in chronic respiratory patients, informing advocacy for air quality measures.

Introduction

Air pollution remains a significant global concern, being placed among the top 10 risk factors for public health issues.[1-3] The detrimental impact of air pollution on health and mortality was documented, with various sources contributing to atmospheric pollution.[4] Fossil fuel-burning vehicles, industrial power plants, and other factors have led to increased global levels of particulate matter (PM), nitrogen dioxide (NO2), ozone (O3), sulfur dioxide (SO2), and carbon monoxide (CO).[5]

There has been a global push to measure and monitor PM levels in response to these escalating evidence.[6] The urgency to safeguard public health has driven extensive efforts to measure and report on air quality indicators globally. Despite these endeavors to tackle air pollution, however, there has been an unfortunate rise in the number of global deaths directly attributed to it,[7] underscoring the urgency of comprehending its impact on public health.[3] In this context, investigating the psychological variables linked to air pollution becomes pivotal to achieving a more holistic understanding of its biopsychosocial implications and implementing measures to alleviate its adverse health effects.

Research on the epidemiological connections between air pollution and early mortality due to cardiovascular and respiratory conditions has been extensive.[8,9] However, there are additional unintended consequences, including discomfort, dissatisfaction, unhappiness, decreased outdoor physical activity, and potential links to aggravation of mental illnesses.[10-14] Daily and long-term exposure to air pollution raises the risk of developing common mental health conditions such as depression.[15-19] Recent studies have attempted to delineate the connection between the physical environment and mental health.[20,21] While green infrastructure has shown positive effects on psychological well-being, outdoor pollutants,[22] particularly PM, have the opposite impact, hindering outdoor physical activities.[23] Furthermore, elevated pollution levels have been linked to chronic stress and even higher COVID-19 mortality.[24-26] Importantly, vulnerable populations, especially those with chronic respiratory disorders, may be disproportionately affected.[27,28]

Given the global evidence of air pollutants as a risk factor for physical and mental health conditions and mortalities, there is still limited evidence of this in Thailand. Therefore, this study aims to explore the relationship between air pollution and psychological distress, specifically

depression, anxiety, and stress, with a focus on a representative group of respiratory patients.

Methods

Study population

This cross-sectional study was conducted at the respiratory disorder clinic of King Chulalongkorn Memorial Hospital in February 2022. Ethical approval was obtained from the Ethical Research Committee, Faculty of Medicine, Chulalongkorn University (ethical approval number: 326/64). The sample size was determined by a moderated effect size of 0.20, assuming a type-1 error rate of 5%, a power (1- β error probability) of 0.95, and a dropout rate of 20%, yielding an expected sample size of 100. All patients visiting the clinic during that period were approached until the required number of participants was met. Individuals aged 18 and above with asthma, chronic obstructive pulmonary disease (COPD), bronchiectasis, or rhinitis were included. They were also required to have a smartphone. Those with severe mental illness or cognitive impairment were excluded. Those who voluntarily agreed to participate were informed that their decision would not affect the quality of their medical care and provided written consent. This sampling strategy aimed to efficiently capture a diverse representation of respiratory patients within the study's ethical framework while ensuring the use of digital tools for data collection.

Questionnaire

Study assistants guided participants in installing the ChulaAir smartphone application. The application collected monthly sociodemographic data, including age, gender, marital status, education, employment, income, alcohol use, other physical illnesses (e.g., cardiovascular disease and hypertension), and family size. Research assistants also reviewed medical records for respiratory diagnoses, which were determined by two physicians using clinical data. Hospital visits and body mass index were extracted from their records.

Air pollution

The verified living residences of the participants underwent a geocoding process. Daily exposure to CO, O_3, NO_2, SO_2, PM of 10 microns or less (PM_{10}), PM of 2.5 microns or less ($PM_{2.5}$), relative humidity, and temperature at each participant's residence was predicted using the ordinary kriging technique.[29] Kriging is a geostatistical interpolation method to predict values at unmeasured locations based on observed values at surrounding locations. The ordinary kriging was applied in this context to generate spatially distributed air pollutant concentrations, providing a comprehensive and interpolated representation of pollutant levels at the residences of the study participants. Real-time hourly concentrations of air pollutants from January 1, 2019, to December 31, 2020, were obtained from the Air Quality Data Subdivision, Air Quality and Noise Management Division, Pollution Control Department, Thailand. Air pollution values were calculated using the single imputation technique (mean imputation) to avoid missing data. To determine the mean of the series of angles in the interval 0° - 360° and find the angle by calculating the inverse tangent, the mean cosine and sine of each angle were calculated. The annual exposure was averaged from daily air pollutant concentrations before assigning to each participant.

Depression, anxiety, and stress

The 21-item Depression Anxiety Stress Scales (DASS-21) was used to assess depression, anxiety, and stress symptoms, with seven questions for each scale totaling twenty-one questions.[30] For each question, a score ranging from 0 to 3 was assigned. A score of 3 meant that the statement applied to the individual most of the time, while a score of 0 indicated that it did not apply to them at all. The final total score of each scale was determined following the DASS-21 recommendation by multiplying each score by two, with higher total scores indicating greater mental difficulty. Typically, for the depression module, scores of at least 10 indicate depressive symptoms; for the anxiety module, scores of at least 7 indicate anxiety symptoms; and for the stress module, scores of at least 11 indicate stress symptoms.[31] Only individuals in this study who achieved scores over the 75th percentile in each domain (depression, anxiety, and stress), however, were deemed positive due to the skewed nature of the data.[32] The Thai version of DASS-21 has excellent psychometric qualities and has been tested on Thai populations.[33]

Statistical analyses

Participants' demographic and clinical data and exposure levels of air pollutants were expressed as percentages or means with standard deviations (SD). Average annual levels of air pollutants were compared between those with and without depression, anxiety, and stress using the independent t-test. Multivariate logistic regression analyses assessed the associations between air pollution and mental health difficulties, adjusting for gender, allergy symptoms, air purifier use, relative humidity, and temperature. The strength of association was presented as an adjusted odds ratio (AOR) with a 95% confidence interval (95% CI). A p-value of less than .05 indicated a statistical significance.

Results

Participants' characteristics

A total of 98 participants with an average age of 55.3 years (SD = 15.1) were included in the study. Most were female (69.4%), married (62.2%), and unemployed (64.3%). Most common respiratory diagnosis was asthma (50.0%), followed by rhinitis (20.4%), bronchiectasis (18.4%), and COPD (11.2%). The prevalence of depression, anxiety, and stress among the participants were 30.6%, 28.6%, and 26.5%, respectively (table 1).

Air pollutant exposure levels

The air pollutant exposure levels are presented in Table 2. The average annual CO, O_3, NO_2, SO_2, PM_{10}, and $PM_{2.5}$ exposed by the participants were 0.9 ppm, 21.4 ppb, 18.2 ppb, 2.6 ppb, 41.0 μg/m^3, and 22.6 μg/m^3, respectively. The average relative humidity and temperature were 72.5% and 29.4°C, respectively. There were no significant differences in annual air pollutant exposure among those with and without mental health difficulties (table 2).

Air pollution and mental health

After adjusting for sociodemographic characteristics, a statistically significant association between long-term $PM_{2.5}$ exposure and depression was observed. Each 1 μg/m^3 increment in long-term $PM_{2.5}$ increased the odds of depression by 1.34 folds (AOR = 1.34, 95% CI = 1.02 - 1.79). However,

Table 1 Sociodemographic and clinical characteristics of participants (N = 98)

	n	%
Age		
Mean (SD)	55.3 (15.1)	
Sex		
Male	30	30.6
Female	68	69.4
Marital status		
Single	27	27.6
Married	61	62.2
Separated	10	10.2
Education		
< Bachelor degree	27	27.6
Bachelor degree	50	51.0
> Bachelor degree	21	21.4
Current employment		
Employed	35	35.7
Unemployed	63	64.3
Monthly income (Thai baht)		
< 25,000	55	56.1
25,000 - 50,000	24	24.5
> 50,000	19	19.4
Smoking		
No	83	84.7
Yes	15	15.3
Alcohol use		
No	80	81.6
Yes	18	18.4
Respiratory disease (as primary diagnosis)		
Asthma	49	50.0
COPD	11	11.2
Bronchiectasis	18	18.4
Rhinitis	20	20.4
Allergy		
No	53	54.1
Yes	45	45.9
Physical illness(es)		
No	46	46.9
Yes	52	53.1
Body mass index (kg/m^2)		
Low (< 18.5)	16	16.3
Healthy (18.5 - 25)	49	50.0
High (> 25)	33	33.7
Number of family members (including participant)		
2 - 3	49	50.0
4 or more	49	50.0

Table 1 Sociodemographic and clinical characteristics of participants (N = 98) (continued)

	n	%
Hospital visit(s) in a previous month		
No	74	75.5
Yes	24	24.5
Air purifier usage in a previous month		
No	48	49.0
Yes	50	51.0
Depression		
No	68	69.4
Yes	30	30.6
Anxiety		
No	70	71.4
Yes	28	28.6
Stress		
No	72	73.5
Yes	26	26.5

COPD = chronic obstructive pulmonary disease

Table 2 Annual ambient residential exposure characteristic

air pollutants	Depression, mean (SD)			Anxiety, mean (SD)			Stress, mean (SD)		
	No (n = 68)	Yes (n = 30)	p§	No (n = 70)	Yes (n = 28)	p§	No (n = 72)	Yes (n = 26)	p§
$PM_{2.5}$ (μg/m^3)	22.42 (2.43)	22.98 (2.88)	.329	22.41 (2.34)	23.06 (3.08)	.312	22.66 (2.55)	22.41 (2.68)	.668
PM_{10} (μg/m^3)	40.63 (4.62)	41.79 (5.85)	.294	40.81 (4.50)	41.42 (6.21)	.644	41.20 (4.91)	40.40 (5.38)	.490
CO (ppm)	0.85 (0.23)	0.87 (0.23)	.692	0.86 (0.22)	0.84 (0.26)	.748	0.84 (0.24)	0.88 (0.23)	.514
O_3 (ppb)	21.43 (3.21)	21.34 (3.03)	.886	21.30 (3.11)	21.67 (3.26)	.613	21.55 (3.24)	21.01 (2.87)	.453
NO_2 (ppm)	18.11 (4.17)	18.50 (4.46)	.676	18.33 (4.12)	17.98 (4.61)	.719	18.13 (4.04)	18.50 (4.84)	.708
SO_2 (ppb)	2.60 (1.14)	2.73 (1.42)	.616	2.63 (1.29)	2.67 (1.08)	.880	2.64 (1.28)	2.65 (1.10)	.978

CO = carbon dioxide, O_3 = ozone, NO_2 = nitrogen dioxide, SO_2 = sulfur dioxide, PM_{10} = particulate matter ≤ 10 μm, and $PM_{2.5}$ = particulate matter ≤ 2.5 μm

§ Independent t-test

no significant associations were found between long-term ambient air pollution and anxiety or stress (table 3).

Discussion

The annual average levels of exposure to CO, O_3, NO_2, SO_2, PM_{10}, and $PM_{2.5}$ of the participants in this study were 0.9 ppm, 21.4 ppb, 18.2 ppb, 2.6 ppb, 41.0 μg/m^3, and 22.6 μg/m^3, respectively, which did not exceed the global standards.[34] However, the average relative humidity and temperature of 72.5% and 29.4°C, respectively, were slightly higher than the global recommendations.[34] While these values offer a snapshot of local air quality, determining whether they surpass global standards necessitates a direct comparison with

Table 3 Associations between air pollution and depression, anxiety, and stress

air pollutants	Depression		Anxiety		Stress	
	AOR (95% CI)	p[§]	AOR (95% CI)	p[§]	AOR (95% CI)	p[§]
$PM_{2.5}$	1.34 (1.02 - 1.79)	.047	1.19 (0.89 - 1.57)	.227	1.04 (0.77 - 1.40)	.816
PM_{10}	1.05 (0.99 - 1.24)	.109	1.01 (0.90 - 1.14)	.837	0.97 (0.85 - 1.10)	.594
CO	1.47 (0.10 - 10.14)	.962	1.06 (0.11 - 10.50)	.960	1.44 (0.13 - 16.23)	.769
O_3	0.99 (0.87 - 1.19)	.798	1.05 (0.89 - 1.22)	.571	0.98 (0.83 - 1.15)	.806
NO_2	1.02 (0.91 - 1.15)	.720	0.98 (0.81 - 1.11)	.746	0.98 (0.87 - 1.11)	.763
SO_2	1.09 (0.66 - 1.59)	.910	0.81 (0.51 - 1.29)	.371	0.88 (0.54 - 1.45)	.816

[§] Multivariate logistic regression, adjusted for gender, allergy symptom, using air purifier, relative humidity, and temperature

AOR = adjusted odds ratio, CO = carbon dioxide (ppm), O_3 = ozone (ppb), NO_2 = nitrogen dioxide (ppb), SO_2 = sulfur dioxide (ppb), PM_{10} = particulate matter ≤ 10 μm (μg/m^3), and $PM_{2.5}$ = particulate matter ≤ 2.5 μm (μg/m^3)

established air quality guidelines such as those set by the World Health Organization (WHO) and national environmental agencies. Further analysis in the light of these benchmarks is crucial to comprehensively assess the potential health implications of the observed air pollution levels.

The investigation of the associations between air pollution and mental health issues revealed that an increase in annual $PM_{2.5}$ exposure corresponded to higher odds of self-reported depression. This can be inferred that prolonged exposure to $PM_{2.5}$ is linked to an elevated risk of depression among chronic respiratory patients. This finding is in line with studies across Asia, Europe, and North America that have consistently emphasized the relationship between air pollution and depression among different populations.[35-40] Similar to the present study, research in China showed a negative effect of increasing $PM_{2.5}$ concentration on depression, which could be mitigated by neighborhood social capital.[41] Moreover, a cohort study among South Korean adults proved that long-term exposure to air pollutants increased suicide due to depression.[42]

Various biological mechanisms could be explained for this relationship. Air pollution increases the risks of cardiovascular and respiratory diseases, which are related to depressive symptoms.[43,44] Therefore, residents of cities with more air pollution have higher risks of cardiovascular diseases, respiratory disease, and depression. Besides, air pollution limits outdoor physical activities and sports, increasing the risk of depression.[45] Moreover, polluted air reduces the amount of sunlight, which is considered a protective factor against depression.[46,47] Some studies have also shown that air pollution introduces social isolation, which in turn exacerbates depressive symptoms.[48-50] In the central nervous system, PM might induce dopaminergic neuronal damage, causing changes in neurotransmitter levels via an inflammatory process. Indeed, inhalation of PM can activate pro-inflammatory cytokines in human macrophages, initiating an inflammatory response and inducing oxidative stress.[51,52] Eventually, oxidative stress and systemic inflammation can cause depression and anxiety-related behaviors.[53] Nevertheless, some studies

show different results. For example, a large community health survey in Canada showed that the relationship between air pollution and depression was not significant.[54]

It is important to note that this study did not account for the severity of respiratory symptoms among the patients. It is reasonable to postulate that individuals with chronic respiratory conditions, already grappling with compromised respiratory function, might experience a worsening of their symptoms when exposed to elevated $PM_{2.5}$ levels over an extended period. This aggravation of respiratory distress could catalyze the onset of mental health symptoms. Moreover, some of the socioeconomic indicators as potential confounders (e.g., financial concerns and living arrangements) were not taken into account. Future research endeavors should consider incorporating these covariates to comprehensively assess the association between pollutant exposure and mental health outcomes. Lastly, the focus on respiratory cases with varying severity, while informative for this specific context, constrained the dataset compared to a broader medical perspective.

Nevertheless, this study contributes additional empirical support that prolonged exposure to air pollution, especially during vulnerable respiratory conditions, may influence psychological distress. Thus, reducing air pollution at individual, local, and regional levels might help alleviate vulnerability to adverse mental health impacts. Addressing the magnitude of air pollution exposure should be a priority for policymakers.

Conclusions

This study has explored a potential link between prolonged exposure to air pollutants and mental health problems among chronic respiratory patients. It demonstrates that a higher level of $PM_{2.5}$ exposure significantly increases the risk of depression. In spite of certain limitations, the finding underscores the possibility of enhancing mental well-being in this demographic through the reduction of air pollution.

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