Original Article

Effect of particulate matter on continuous positive airway pressure adherence in obstructive sleep apnea patients

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Background: Sleep quality could be affected by air pollution, especially for particulate matter with a diameter of less than 10 microns (PM_{10}) and particulate matter with a diameter of less than 2.5 microns ($PM_{2.5}$). However, no direct study demonstrates the relationship and impact of air pollution especially PM_{10} and $PM_{2.5}$ on continuous positive airway pressure (CPAP) adherence. Thus, we aimed to study the correlation between PM_{10}, $PM_{2.5}$, and low CPAP adherence in subjects with obstructive sleep apnea (OSA).

Methods: We conducted a time-series study from August 2016 to May 2022 in Chiang Mai, Thailand. The data from 2,686 visits of CPAP compliance records from 839 OSA patients' electronic medical records at the Sleep Disorders Center, Center of Medical Excellence, Chiang Mai University, Chiang Mai, Thailand were reviewed. The level of adherence was determined utilizing the provided data. Low CPAP adherence was defined as using CPAP for less than 240 minutes per night or less than 70% of nights (i.e., <5 nights/week) in the previous month. The correlation between the monthly average of PM_{10} and $PM_{2.5}$ and the rate of low CPAP adherence was analyzed using generalized linear mixed model (GLMM) after adjustment for confounding factors.

Results: There was no effect of an increase in PM_{10} and $PM_{2.5}$ on low CPAP adherence [adjusted risk ratio (RR) =0.97; 95% confidence interval (CI): 0.87, 1.09; P value =0.624 and adjusted RR =0.93; 95% CI: 0.81, 1.08; P value =0.350 for PM_{10} and $PM_{2.5}$, respectively].

Conclusions: There was no effect of particulate matter on CPAP adherence in OSA patients.

Keywords: Pollution; continuous positive airway pressure (CPAP); obstructive sleep apnea (OSA); compliance; adherence

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Introduction

Obstructive sleep apnea (OSA) is a prevalent sleep disorder that impacts 3–9% of the general population and it has been identified as a risk factor for a range of health conditions, including hypertension, cardiovascular disease, neurological disorders, and psychiatric illnesses (1). The utilization of continuous positive airway pressure (CPAP) is a highly efficacious approach for treating OSA and is widely regarded as the preeminent therapeutic intervention for this condition. However, the adherence of patients to this treatment is crucial for its overall effectiveness (2-4). The efficacy of CPAP therapy is closely linked to adherence to treatment, rendering it a highly effective intervention. Nevertheless, ensuring adherence to CPAP therapy continues to pose difficulties. The CPAP therapy is recommended to be administered throughout the entirety of a patient's sleep cycle. However, it has been observed that this protocol is only adhered to by a minority of subjects in practical settings.

Numerous studies have demonstrated that a variety of factors including subjective sleep-related symptoms, the OSA severity, awareness of CPAP's effects and side effects, and discomfort affect adherence to CPAP therapy (5-7). Our recent study has also shown that low CPAP adherence in elderly OSA patients are caused by females gender, personal life issues and adverse attitudes towards treatment, and health issues (8).

The issue of air pollution holds significant global importance. The majority of the global population resides in regions where the concentrations of air pollutants surpass the thresholds established by the World Health Organization (WHO) guidelines, with a percentage exceeding 90%. Air pollution is a major problem in Chiang Mai, Thailand. During pre-summer and summer seasons (January–April), air pollutant levels especially for particulate matter with a diameter of less than 2.5 microns ($PM_{2.5}$) usually exceed the WHO safety threshold. For over a decade, the correlation between air pollution and adverse health consequences in this region has been acknowledged especially in subjects with cardiopulmonary diseases (9-14).

Sleep quality could be affected by air pollution, especially for particulate matter with a diameter of less than 10 microns (PM_{10}) and $PM_{2.5}$ (15-20). Previous studies showed that the particular matter (PM) was associated with an increase in apnea-hypopnea index (AHI) both without and even while using CPAP (15,16,19). Moreover, significant changes in sleep parameters including oxygen desaturation index, and total sleep time with peripheral capillary oxygen saturation (SpO_2) lower than 90% in chronic obstructive pulmonary disease (COPD) patients with OSA were also found (20). Currently, no direct study demonstrates the relationship and impact of air pollution especially PM_{10} and $PM_{2.5}$ on CPAP adherence. Therefore, we aimed to study the association between PM_{10}, $PM_{2.5}$, and low CPAP adherence in subjects with OSA. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1507/rc).

Highlight box

Key findings

- There was no effect of particulate matter on continuous positive airway pressure (CPAP) adherence in obstructive sleep apnea (OSA) patients.

What is known and what is new?

- Sleep quality could be affected by particulate matter with a diameter of less than 10 microns (PM_{10}) and particulate matter with a diameter of less than 2.5 microns ($PM_{2.5}$).
- Air pollution especially for PM_{10} and $PM_{2.5}$ were not associated with low CPAP adherence in OSA patients.

What is the implication, and what should change now?

- Air purifiers should be still suggested for CPAP users during high air pollution periods.

Methods

Design and study participants

We conducted a time-series study from August 2016 to May 2022 in Chiang Mai, Thailand. The data from 2,686 visits of CPAP compliance records from 839 OSA patients' electronic medical records at the Sleep Disorders Center, Center of Medical Excellence, Chiang Mai University, Chiang Mai, Thailand were reviewed. The evaluation of compliance with CPAP therapy was consistently conducted through the objective analysis of the electronic data recording of CPAP devices. The level of adherence was determined utilizing the provided data. Low CPAP adherence was defined as using CPAP for less than 240 minutes per night or less than 70% of nights (i.e., <5 nights/week) (21). We used an average data of CPAP adherence in the previous month. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Research Ethics

Table 1 Baseline demographic of subjects with OSA

Characteristics	Values
Age (years)	56.6±14.7
Sex (male)	296 (35.3)
BMI (kg/m^2)	27.8±5.6
Neck circumference (inch)	15.5±2.1
Waist circumference (inch)	39.3±8.9
Comorbidities	
Coronary artery disease	7 (0.8)
COPD	6 (0.7)
Diabetes mellitus	31 (3.7)
Hypertension	80 (9.5)
EDS defined by ESS	485 (57.8)
AHI total	71.1 (53.9, 90.3)
AHI REM	0.0 (0.0, 53.8)
AHI non-REM	72.8 (53.9, 92.1)

Values are presented as mean ± SD, n (%), or median (IQR). OSA, obstructive sleep apnea; BMI, body mass index; COPD, chronic obstructive pulmonary disease; EDS, excessive daytime sleepiness; ESS, Epworth Sleepiness Scale; AHI, apnea-hypopnea index; REM, rapid eye movement; SD, standard deviation; IQR, interquartile range.

Committee of the Faculty of Medicine, Chiang Mai University [Institutional Review Board (IRB) approval number: MED-2565-09282, date of approval 18 November 2022]. Individual consent for this retrospective analysis was waived.

Measurements of air pollutants

The measurements of air quality were recorded by Air Quality and Noise Management, Division Pollution Control Department, Thailand, and the sampling station is located at the center of Muang District, Chiang Mai Province, Thailand (22). Monthly average concentrations for PM_{10}, $PM_{2.5}$, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3) were recorded. However, the monthly average concentration of carbon monoxide (CO) has not been available in Chiang Mai station since July 2016. The meteorological data including temperature, atmospheric pressure, rain, relative humidity, and wind speed were obtained from the Northern Meteorology Center, Chiang Mai province on an average monthly basis (23). We retrieved data from August 2016 to May 2022 in parallel with CPAP adherence data.

Statistical analysis

Results for continuous data were shown as mean ± standard deviation (SD) or median and interquartile range (IQR). The categorical data were expressed as absolute frequencies and percentages. The correlation coefficients among the air pollutants were calculated using Pearson's correlation (r). The correlation between the monthly average of PM_{10} and $PM_{2.5}$ and the low CPAP adherence was analyzed using generalized linear mixed model (GLMM) after adjustment for other ambient pollutants including SO_2, NO_2, O_3, meteorological parameters including temperature, atmospheric pressure, rain, relative humidity, and wind speed, age, sex, personal life issues, and adverse attitudes towards CPAP treatment, and health conditions. The correlation between the monthly average concentrations of PM_{10} and $PM_{2.5}$ and the rate of low CPAP adherence was examined for the lag of 0 months. The month of an increase in monthly average PM_{10} and $PM_{2.5}$ were defined as lag time 0 (lag0). Results were displayed as adjusted risk ratios (RRs) with 95% confidence intervals (CIs). Model calibration was evaluated using a calibration plot between observed (actual) risk and expected (predicted) risk. Statistical significance was accepted at a P value less than 0.05. We used StataCorp version 16.1, College Station, TX, USA) for statistical analysis.

Results

There was a total of 2,686 visits from 839 OSA patients from August 2016 to May 2022. The patients' characteristics are shown in *Table 1*. The mean age was 56.6±14.7 years old, with 296 (35.3%) males. More data are shown in *Table 1*.

The monthly average PM_{10} and $PM_{2.5}$ and number of low CPAP adherence throughout the study period is shown in *Figure 1*. PM_{10} and $PM_{2.5}$ levels increased during dry season (January–April) of every year.

The correlation coefficients among the air pollutants are shown in *Table 2*. There was a high correlation between PM_{10} and $PM_{2.5}$ with r=0.996.

The effect of every 10 μg/m^3 increase in PM_{10} and $PM_{2.5}$ on low CPAP adherence was demonstrated in *Table 3*. There was no effect of an increase in PM_{10} and $PM_{2.5}$ on low CPAP adherence after adjustment for confounding factors

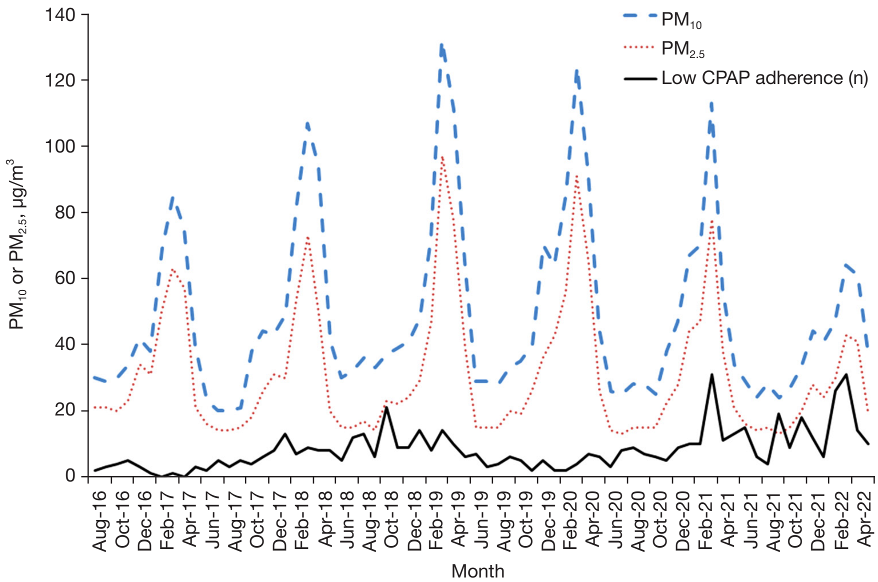

Figure 1 The monthly average PM_{10} and $PM_{2.5}$ and number of low CPAP adherence throughout the study period. PM_{10}, particulate matters with diameter of less than 10 microns; $PM_{2.5}$, particulate matters with diameter of less than 2.5 microns; CPAP, continuous positive airway pressure.

Table 2 Correlation coefficients among the air pollutants

Pollutants	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	O_3 (ppb)	NO_2 (ppb)	SO_2 (ppb)
PM_{10} (μg/m^3)	1.000				
$PM_{2.5}$ (μg/m^3)	0.996	1.000			
O_3 (ppb)	0.836	0.818	1.000		
NO_2 (ppb)	0.658	0.663	0.529	1.000	
SO_2 (ppb)	0.246	0.246	0.210	0.138	1.000

PM_{10}, particulate matters with diameter of less than 10 microns; $PM_{2.5}$, particulate matters with diameter of less than 2.5 microns; O_3, ozone; NO_2, nitrogen dioxide; SO_2, sulfur dioxide.

including SO_2, NO_2, and O_3, temperature, atmospheric pressure, rain, relative humidity, and wind speed, age, sex, personal life issues and adverse attitudes towards CPAP treatment, and health conditions (adjusted RR of 0.97; 95% CI: 0.87, 1.09; P value =0.624 and 0.93; 95% CI: 0.81, 1.08; P value =0.350 for PM_{10} and $PM_{2.5}$, respectively). We also found no effect of an increase in PM_{10} and $PM_{2.5}$ on low CPAP adherence in stratified analysis for sex (male and female) and age group (<60 and ≥60 years).

Model calibration was evaluated using a calibration plot between observed (actual) risk and expected (predicted) risk which was shown in *Figure 2*.

Discussion

CPAP is a highly efficacious treatment of OSA which has been linked with a range of health conditions. The adherence of patients to this treatment is crucial for its overall effectiveness (2-4). Our study found no effect of an increase in PM_{10} and $PM_{2.5}$ on low CPAP adherence in OSA patients. However, previous studies showed impaired sleep quality caused by air pollution (15-20) and the association of PM and the increasing of AHI both without and while using CPAP through the multiple hypotheses such as the upper airway irritation, the damage of airway epithelium

Table 3 Associations between every 10 μg/m³ increase of PM_{10}, $PM_{2.5}$, and low CPAP adherence

Pollutions	Adjusted risk ratios (95% CI)†	P value
Total subjects		
PM_{10} (μg/m³)	0.97 (0.87, 1.09)	0.624
$PM_{2.5}$ (μg/m³)	0.93 (0.81, 1.08)	0.350
Male		
PM_{10} (μg/m³)	0.95 (0.20, 1.12)	0.521
$PM_{2.5}$ (μg/m³)	0.91 (0.73, 1.12)	0.383
Female		
PM_{10} (μg/m³)	0.99 (0.86, 1.15)	0.899
$PM_{2.5}$ (μg/m³)	0.95 (0.79, 1.14)	0.599
Age <60 years		
PM_{10} (μg/m³)	0.89 (0.75, 1.07)	0.227
$PM_{2.5}$ (μg/m³)	0.84 (0.67, 1.06)	0.135
Age ≥60 years		
PM_{10} (μg/m³)	1.03 (0.89, 1.19)	0.693
$PM_{2.5}$ (μg/m³)	1.00 (0.84, 1.20)	0.983

†, adjusted for age, sex, other pollutants including SO_2, NO_2, and O_3, meteorological parameters including temperature, atmospheric pressure, rain, relative humidity, and wind speed, age, sex, personal life issues and adverse attitudes, and health-related problems. PM_{10}, particulate matter with a diameter of less than 10 microns; $PM_{2.5}$, particulate matter with a diameter of less than 2.5 microns; CPAP, continuous positive airway pressure; CI, confidence interval; SO_2, sulfur dioxide; NO_2, nitrogen dioxide; O_3, ozone.

and the changes in oxidative stress, the inflammation and autonomous nervous system control (15,16,19). From our explanatory research, we showed that the low CPAP adherence in subjects with OSA was not caused by the PM_{10} and $PM_{2.5}$ but low adherence was associated with other factors including personal life issues and adverse attitudes towards CPAP treatment as well as health conditions which were supported by the previous study (8).

Our study is one of the discoveries in the pioneer era of air cleanness and OSA treatment using direct pollution levels to demonstrate the relationship and impact of air pollution especially PM_{10} and $PM_{2.5}$ on CPAP adherence in subjects with OSA. However, we found no association between PM_{10} and $PM_{2.5}$ on CPAP adherence. This could be explained that newer generation CPAP has more effective air filter system for inlet air purification, this factor might benefit the patient from the negative effects of the polluted air while using. However, further studies to explore the precise mechanism of the air quality and the CPAP tolerability in OSA patients are still required.

Our strength of this study is the first study on the effect of ambient air pollution on CPAP adherence in OSA patients. However, this study has some limitations. Firstly, the air pollution was measured at only one site that located in the central area of Chiang Mai, Thailand. Therefore, it may not be the same level across the entire area. However, all OSA subjects live in the same part of the country and all the pollution levels and exposure usually exceed the safety threshold defined by WHO during dry season (January–April) of the year. Secondly, monthly average of PM_{10} and $PM_{2.5}$ and monthly average of CPAP adherence were used

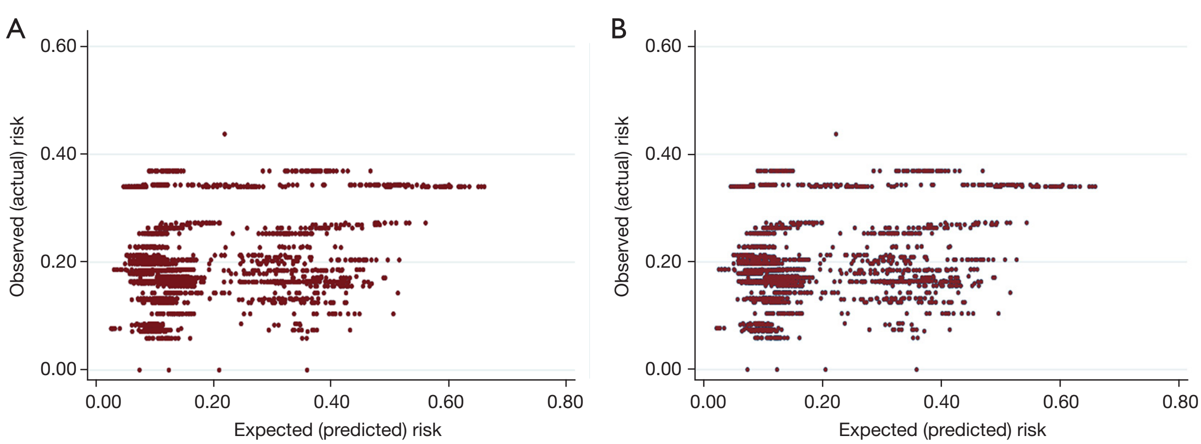

Figure 2 Model calibration was evaluated using a calibration plot between observed (actual) risk and expected (predicted) risk. (A) PM_{10}; (B) $PM_{2.5}$. PM_{10}, particulate matter with a diameter of less than 10 microns; $PM_{2.5}$, particulate matter with a diameter of less than 2.5 microns.

for analysis. This caused no association between PM_{10} and $PM_{2.5}$ on CPAP adherence in our study. Therefore, the correlation between daily PM_{10} and $PM_{2.5}$ and CPAP adherence should be focused in future studies.

Conclusions

Our study concluded that there was no an effect of PM_{10} and $PM_{2.5}$ on low CPAP adherence in OSA patients. However, air purifiers should be still suggested for CPAP users during high air pollution periods for cardiorespiratory health benefits as demonstrated in previous studies.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Research Ethics Committee of the Faculty of Medicine, Chiang Mai University [Institutional Review Board (IRB) approval number: MED-2565-09282, date of approval 18 November 2022]. Individual consent for this retrospective analysis was waived.

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