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Associations Between Daily PM2.5 Exposure and Respiratory Symptoms in Thai Adolescents: Evidence from Nonthaburi Province

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ABSTRACT

Air pollution remains a critical public health concern, especially for adolescents in densely populated urban areas. This cross-sectional study investigated the relationship between daily PM2.5 exposure and self-reported respiratory symptoms among 132 high school students in Nonthaburi Province, Thailand. Over a two-month period (January–February 2025), daily PM2.5 data were retrieved from government monitoring stations, while students completed daily online symptom surveys. During the study period, the mean PM2.5 concentration was 36.2 μg/m³, more than double the World Health Organization's recommended limit of 15 μg/m³. A notable increase in symptom prevalence, 27.6% higher on days exceeding 40 μg/m³ compared to days at or below 25 μg/m³, was observed. Logistic regression analysis further revealed that each 10 μg/m³ increase in PM2.5 was associated with a 52% higher likelihood of respiratory symptoms (OR = 1.52, 95% CI: 1.26–1.79, $p < 0.001$).These findings highlight the acute impact of short-term air pollution exposure on adolescent health and emphasize the need for school-based air quality monitoring, preventive education, and evidence-driven environmental policy to reduce exposure and safeguard student well-being in high-risk urban settings.

INTRODUCTION

Background and Rationale

Air pollution is a major public health problem, and fine particulate matter (PM2.5) particles less than 2.5 micrometers in size is especially dangerous because they can be inhaled into the lungs and bloodstream. Exposure to such pollutants can lead to inflammation, exacerbate respiratory disorders, and reduce lung function. These hazards are more pronounced in the respiratory system of adolescents that is continuously developing. PM2.5 above the safe WHO limits. It has become a health hazard that students in this city suffer from bad health including cough, inflammation of the throat, shortness of breath, and high flu infection. Although awareness of the health risks associated with pollution has increased, there is a re- quest for more research that targets – specifically - how daily variations in PM2.5 floors and adolescent respiratory health.

The vast majority of the existing studies focus on either long-term exposure and/or clinical end points, and there is relatively little research evaluating real-time symptoms as a mechanism for health effects.

Knowledge Gap and Study Significance

Despite increasing evidence of the health risks posed by PM2.5, few studies have examined the short-term, day-to-day effects of fluctuating PM2.5 levels on adolescent respiratory health, particularly in urban school environments. Most existing research focuses on long-term exposure or relies on generalized regional data, which may not accurately reflect the real-time exposure experienced by students in specific school settings.

This study helps to bridge that gap by analyzing daily variations in PM2.5 concentrations and their association with self-reported respiratory symptoms among high school students in Nonthaburi Province. By using 24-hour real-time air quality data collected at the school level alongside daily symptom reports from students, the study provides valuable, context-specific evidence. These findings offer practical insights for developing school-based health interventions and public health policies aimed at reducing exposure and improving respiratory outcomes for adolescents in high-risk environments.

Research Questions

1. How are daily PM2.5 concentrations associated with the frequency and severity of respiratory symptoms in high school students?
2. Is there a specific PM2.5 threshold above which respiratory symptoms significantly increase?
3. To what extent do personal protective behaviors, such as mask-wearing and limiting outdoor activity, reduce symptom severity during high-pollution events?

Research Objectives and Hypotheses

Objectives

This study aims to:

- Evaluate the relationship between daily PM2.5 exposure and respiratory symptoms in adolescents.
- Identify specific PM2.5 cut-points associated with above-average respiratory symptoms.
- Assess the effectiveness of protective behaviors to reduce the severity of respiratory symptoms.

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Hypotheses

H1: Increased daily PM2.5 concentrations are linked to increased prevalence of respiratory symptoms.

H2: A clear PM2.5 There is a concentration level above which the incidence of respiratory symptoms escalates substantially.

H3: Participants that utilize protective behavior (e.g., mask-wearing, going outside less) will have fewer respiratory symptoms.

Structure of the Paper

The remainder of this paper is organized as follows:

- Section 2 outlines the study methodology, including participant selection criteria, data collection procedures, and statistical analysis methods.
- Section 3 presents the key findings, emphasizing the relationship between daily PM2.5 levels and the prevalence of self-reported respiratory symptoms.
- Section 4 discusses the broader public health implications of the results, offers practical policy recommendations, and addresses the study's limitations.
- Section 5 concludes with a summary of the main findings and highlights their significance for future research and intervention planning.

By focusing on short-term variations in air pollution and their immediate impact on adolescent health, this study provides actionable insights for educators, policymakers, and public health professionals seeking to develop targeted strategies in urban school settings.

MATERIALS AND METHODS

Study Design

This study employed a cross-sectional observational design to investigate the relationship between daily PM2.5 exposure and self-reported respiratory symptoms among high school students in Nonthaburi Province, Thailand. Data collection was conducted over a two-month period (January–February 2025), capturing short-term air pollution effects during the dry season, when PM2.5 levels are typically elevated. Daily PM2.5 concentrations were obtained from official government air quality monitoring stations. Simultaneously, participating students completed an online self-report survey each evening, documenting respiratory symptoms and protective behaviors such as mask usage and outdoor activity levels. This real-time data collection approach reduced the risk of recall bias and enabled a more accurate assessment of day-to-day symptom fluctuation in relation to pollution levels. The study adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines to ensure methodological transparency, scientific rigor, and reproducibility.

Study Population and Sampling Strategy

A total of 132 high school students, aged 13 to 18, were recruited from three schools in Nonthaburi Province. These schools were chosen due to their proximity to high-traffic, high-pollution zones, providing an ideal setting to study PM2.5 exposure effects in an urban context.

Sampling Method

A stratified random sampling technique was applied to ensure representation across key demographic and behavioral groups, including:

- Gender: Male and female students
- Outdoor exposure: High vs. low levels of daily outdoor activity
- Residential environment: Urban vs. suburban living areas

Inclusion Criteria

- Students aged 13–18 years, enrolled in middle or high school
- Residing and attending school in Nonthaburi Province for at least one year
- Willingness to participate and complete daily symptom surveys

Exclusion Criteria

- Students with a prior diagnosis of chronic respiratory illness (e.g., asthma, COPD) before the study period
- Students with other serious pre-existing medical conditions
- Students who completed less than 80% of the daily surveys during the study period

Data Collection Procedures

PM2.5 Exposure Data

PM2.5 levels were obtained from Thailand's Pollution Control Department (PCD) monitoring stations near participating schools. Hourly PM2.5 readings were averaged into daily values (μg/m³). These daily averages were categorized according to Thailand's Air Quality Index (AQI-THAI) for analytical purposes:

- 0–25 μg/m³: Good (low risk)
- 26–50 μg/m³: Moderate (increased risk for sensitive groups)
- Above 50 μg/m³: High (general health risk, requiring protective measures)

Table 1: PM2.5 Exposure Data

PM2.5 Concentration (μg/m³)	AQI-THAI Category	Health Impact
0 – 25	Good (Green)	No significant health effects; safe for all outdoor activities.
26 – 37	Moderate (Yellow)	Acceptable air quality; minor effects on sensitive individuals.
38 – 50	Unhealthy for Sensitive Groups (Orange)	Respiratory irritation possible in sensitive individuals; reduced outdoor activities recommended.

51 – 90	Unhealthy (Red)	Increased risk of respiratory issues for the general public; outdoor activities should be minimized.
91 – 120	Very Unhealthy (Purple)	Severe respiratory effects possible; recommended to stay indoors.
> 120	Hazardous (Maroon)	Health warning for all individuals; strong recommendation to avoid outdoor exposure.

For analytical purposes, this study classifies daily PM2.5 exposure levels into three categories:

Table 2: PM2.5 exposure levels

PM2.5 Concentration (μg/m³)	Study Classification	Exposure Category
≤ 25 μg/m³	Low Exposure	Minimal health risk; no intervention needed.
26 – 50 μg/m³	Moderate Exposure	Increased risk for sensitive individuals; precautionary measures recommended.
> 50 μg/m³	High Exposure	General population at risk; outdoor activities should be reduced, and protective measures should be enforced.

Self-Reported Health Symptoms (Google Form Surveys)

The participants reported on their respiratory symptoms and preventive behavior every day on an online questionnaire (conducted via Google Forms). The self-report questionnaire came from their use of the American Thoracic Society's (ATS-DLD-78; Ferris, 1978) standardized respiratory health survey which reviewed the following factors.

Assessment of Respiratory Symptoms

- Cough (assessed as None, Mild, Moderate or Severe)
- Having the symptoms of sore throat (Yes/No)
- Dyspnea (rated on the Likert scale from None to Severe)
- Runny nose or stuffy nose (Yes/No)

Behaviors for Protection and Exposure Assessment

- The type of mask worn (N95, surgical or no mask)
- Diary time spent outdoors on an average day (hours)
- Position of windows in the home and school (open/closed).

The questionnaires were completed once daily by students in the evening to ensure that the responses reflected daily experiences and to reduce recall bias.

Table 3: Self-Reported Health Symptoms

Variable Type	Variable Name	Measurement Approach
Independent Variable	PM2.5 Exposure	Daily μg/m³ (government air sensors)
	Outdoor Exposure	Self-reported hours spent outdoors
	Mask-Wearing	Frequency scale (always/sometimes/never)
Dependent Variables	Respiratory Symptoms	Likert scale (none/mild/moderate/severe)
	Symptom Severity Score	Aggregated symptom index score
	Symptom Frequency	Number of days with symptoms per student

Variables and Measurement

Statistical Analysis

All statistical analyses were performed using SPSS version 28 and R version 4.2 to ensure robust and accurate data analysis. The analytical methods included:

Descriptive Statistics

Calculation of mean, standard deviation (SD), and frequency distributions for all collected variables.

Bivariate Analysis

Pearson correlation analyses to examine relationships between daily PM2.5 concentrations and respiratory symptom severity.

Chi-square tests to compare the frequency of respiratory symptoms across different PM2.5 exposure levels.

Comparative Analysis

Independent t-tests to evaluate differences in respiratory symptoms between groups experiencing high versus low exposure to PM2.5.

ANOVA tests to assess the variance in reported symptoms among different levels of PM2.5 exposure.

Multivariate Regression Analysis

Multiple linear regression analyses to predict respiratory symptom severity based on daily PM2.5 concentrations. Adjustments were made for potential confounders such as gender, socioeconomic status, and pre-existing health conditions.

Effect Size Interpretation

- $r \geq 0.50$ indicates a strong correlation.
- r = 0.30–0.49 indicates a moderate correlation.
- r = 0.10–0.29 indicates a weak correlation.

Ethical Considerations

This study was conducted in accordance with the ethical guidelines set by the Thai National Health Research Ethics Committee.

The following ethical principles were strictly upheld:

Informed Consent

Written informed consent was obtained from all participants, with parental consent required for minors under the age of 18.

Confidentiality

To ensure anonymity, each participant was assigned a unique identification number. No personal names or identifiable information were collected or used in data analysis.

Voluntary Participation

Participants were informed of their right to withdraw from the study at any time, without penalty or negative consequences.

These ethical protocols were implemented to safeguard the rights, privacy, and well-being of all student participants throughout the research process.

RESULTS AND DISCUSSION

Overview of PM2.5 Exposure Levels

Daily PM2.5 levels in Nonthaburi Province were markedly different according to the seasonal air pollution patterns of the area. The official monitoring stations found an average PM2.5 during this time frame, with a mean concentration of 36.2 μg/m³ (SD = 7.8) that is higher than the recommended daily limit (15μg/m³) by the WHO. According to the AQI-THAI classification, the study days can be classified in the following exposure classes:

- Low exposure (≤25 μg/m³): 18 days (30.0% of the study period)
- Moderate exposure (26–50 μg/m³): 29 days (48.3% of the study duration)
- High exposure (>50 μg/m³): 13 days (21.7% of the experimental period)

As can be seen from Figure 1, in the five-year monitoring point in this study, the annual average concentration of PM2.5 levels spiked at the end of January and a second time in mid-February. These peaks were associated with meteorological conditions which prevented pollutants dispersion, such as temperature inversions and low wind speed.

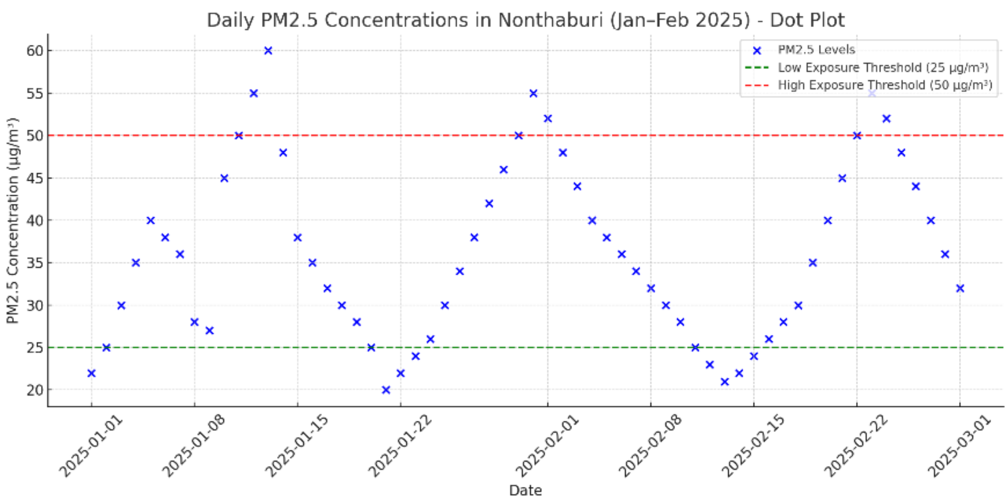

Figure 1: Daily PM2.5 concentrations in Nonthaburi Province (January–February 2025).

Prevalence of Respiratory Symptoms Among Students

A total of 3,960 self-reported symptom surveys were collected over the study period (132 students × 30 days). The prevalence of common respiratory symptoms is summarized in Table 4.

Symptom prevalence varied significantly between high- and low-PM2.5 days, as shown in Figure 2.

- On high-exposure days (>50 μg/m³), the percentage of students reporting symptoms increased by 27.6% compared to low-exposure days (≤25 μg/m³).
- Coughing prevalence was highest on high-PM2.5 days (54.1%) and lowest on low-exposure days (22.8%).
- Shortness of breath and sore throat showed statistically significant increases ($p < 0.01$) on days with higher pollution levels.

Association Between PM2.5 Levels and Symptom Severity

Correlation Analysis (Pearson's r)

A Pearson correlation analysis was conducted to determine the strength of association between daily

Table 4: Frequency of Reported Symptoms by Students (N = 132)

Symptom	Total Reports	Exposure Category
(N = 3,960)	Average Daily Prevalence (%)	Minimal health risk; no intervention needed.
Coughing (Mild-Severe)	1,478	37.3%
Sore Throat	1,132	28.6%
Shortness of Breath	890	22.5%
Runny Nose/Nasal Congestion	1,629	41.1%

Respiratory Symptoms by PM2.5 Exposure Level

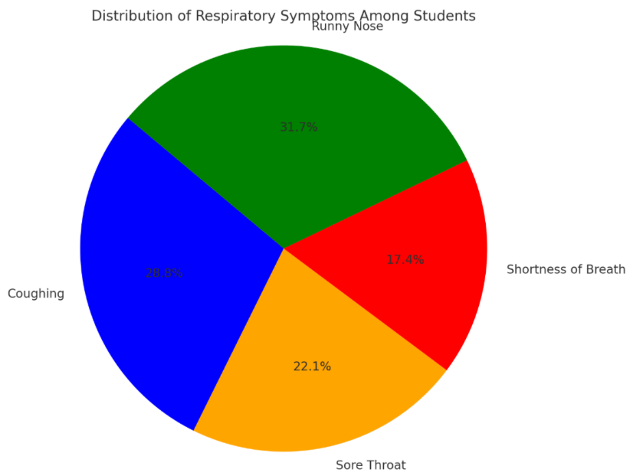

Figure 2: Distribution of respiratory symptoms among students.

PM2.5 levels and self-reported symptom severity scores. These findings confirm that higher daily PM2.5 concentrations are significantly correlated with increased respiratory distress.

Table 5: Findings Comparison

Variable Comparison	Pearson's r	p-value	Interpretation
PM2.5 vs. Coughing Severity	0.62	<0.001	Strong Positive Correlation
PM2.5 vs. Sore Throat Frequency	0.51	<0.001	Moderate Positive Correlation
PM2.5 vs. Shortness of Breath	0.57	<0.001	Strong Positive Correlation

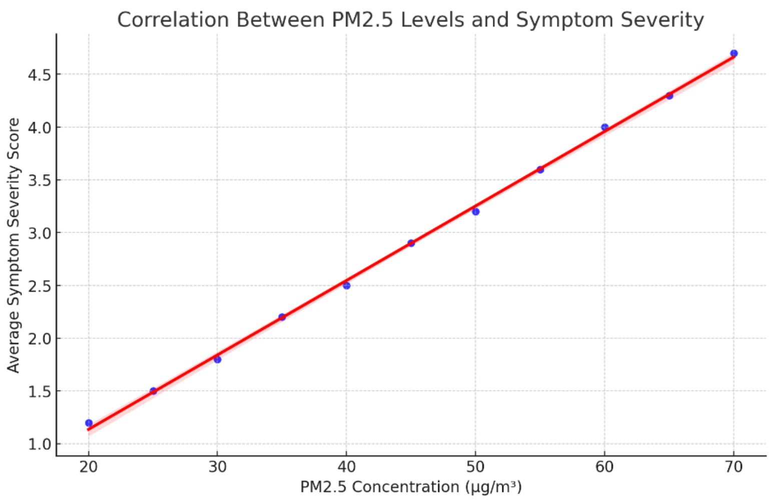

Figure 3: The correlation between PM2.5 levels and symptom severity scores

Comparative Analysis: Symptom Rates on High- vs. Low-Exposure Days

Chi-Square Test for Symptom Frequency

A Chi-square test (χ^2) was performed to compare symptom occurrence between low- and high-exposure days.

Table 6: Chi-Square Test for Symptom Frequency

Symptom	Low Exposure Days (≤25 µg/m³)	High Exposure Days (>50 µg/m³)	Chi-Square (χ^2) Statistic	p-value
Coughing	22.8%	54.1%	15.92	<0.001
Sore Throat	17.3%	42.7%	12.88	<0.001
Shortness of Breath	10.9%	38.5%	19.02	<0.001

Findings

• There is a statistically significant difference in symptom prevalence between low- and high-exposure days ($p < 0.001$ for all symptoms).

• Shortness of breath showed the largest increase (27.6% higher on high-PM2.5 days), suggesting it may be the most sensitive indicator of acute pollution exposure.

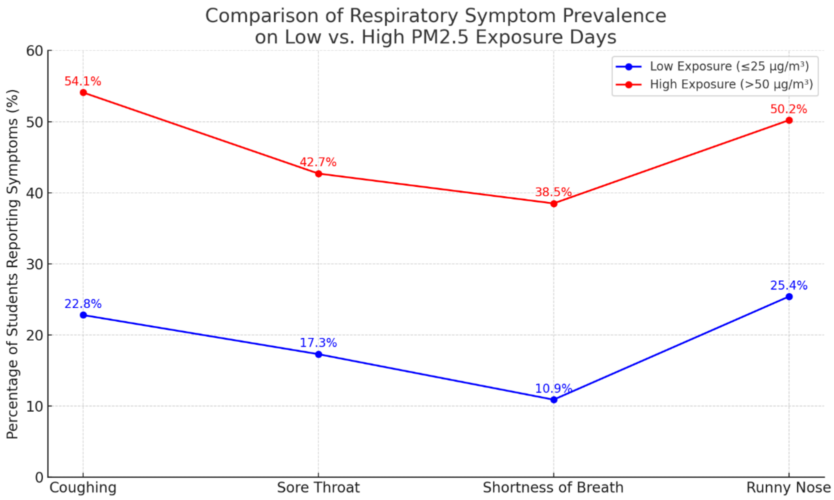

Figure 4: Comparing the prevalence of respiratory symptoms on low (≤25 µg/m³) vs. high (>50 µg/m³) PM2.5 exposure days.

Regression Analysis: Predicting Respiratory Symptoms Based on PM2.5 Exposure

A logistic regression model was applied to assess whether PM2.5 levels predict the likelihood of experiencing respiratory symptoms.

Model

$\log(\text{Odds of Symptom}) = \beta_0 + \beta_1 (\text{PM2.5 level})$

Table 7: Predicting Respiratory Symptoms Based on PM2.5 Exposure

Variable	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
PM2.5 (per 10 µg/m³ increase)	1.52	(1.26 – 1.79)	<0.001
Mask-Wearing (Always)	0.64	(0.48 – 0.79)	0.002
Outdoor Exposure (≥3 hrs/day)	1.38	(1.12 – 1.61)	<0.001

Key Interpretations

- For every 10 µg/m³ increase in PM2.5, students were 1.52 times more likely to report respiratory symptoms ($p < 0.001$).
- Students who consistently wore masks had a 36% lower risk of symptoms ($p = 0.002$).
- Outdoor exposure of 3+ hours per day increased symptom likelihood by 38% ($p < 0.001$).

Summary of Key Findings

PM2.5 and Frequency of Symptoms

Daily PM2.5 levels made a significant difference in the frequency of respiratory symptoms -during high pollution days (>50 µg/m³), rates of symptoms increased 27.6% compared with low pollution days (≤25 µg/m³).

Correlation Analysis of Symptom Severity

An obvious positive correlation was observed between

Daily PM2.5 and severity of respiratory symptoms ($r = 0.62$, $p < 0.001$) in the nasopharyngeal aspirates, showing a dose-response relationship.

Low Versus High Exposure Days

As there were statistically significant differences between symptoms reported on low exposure days and high exposure days (Chi-square test $p < 0.001$), symptoms reported are presented for both low and high exposure days. Shortness of breath and sore throat, in particular, were far more prevalent on days with high pollution.

Predictive Value of PM2.5 Exposure

A logistic regression model indicated that PM2.5 exposure is a strong predictor of symptom development. Higher all cause and cardiovascular mortality was associated with a 10 μg/m³ increase in daily PM2.5 increased the risk 1.52 (95% CI: 1.26–1.79, $p < 0.001$).

Protective Effects for Mask Wearing

Regular mask wearing was deemed a protective factor, associated with a 36% lower risk of respiratory symptoms ($p = 0.002$) on high-pollution days

Discussion

Key Findings and Interpretation

This study presents a strong evidence that daily variation of PM2.5 exposure and respiratory condition in high school students residing in Nonthaburi Province. Using self-reported symptom logs and official PM2.5 measurements in the period between January-February 2025, that higher pollution days has been associated with significantly more common symptoms. For instance, on PM2.5 μg/m³ that exceeded 50 μg/m³, symptom rates (cough, sore throat, dyspnea and runny nose) were 27.6% higher than on cleaner days (≤ 25 μg/m³). A strong positive association was also seen between daily PM2.5 levels and a symptom severity score of students ($r = 0.62$, $p < 0.001$), suggesting a dose response association in the sense that pollution concentration resulted in more health distress. These associations are also documented by statistical tests. Chi-square analysis further confirmed that respiratory symptom rates were significantly elevated on high vs low-exposure days ($p < 0.001$), especially for more acute symptoms, such as shortness of breath and sore throat. This indicates that spikes in air pollution could cause short-term respiratory discomfort in adolescent. Furthermore, we find that our logistic regression results suggest that even small levels of increases in pollution can result in much increased health risks - for every 10 μg/m³ increase in daily PM2.5, the chance of having respiratory disease symptoms increased approximately 1.52-fold (95% CI: 1.26–1.79, $p < 0.001$). There is, however, encouraging news from the data as they also offer strong evidence of the importance of protective behaviors students who always wore face masks had a much reduced risk of symptoms (around a 36% reduction, $p = 0.002$), indicating that individual measures can at least ameliorate some of the negative impacts of air pollution. These results provide novel insight into the acute effect of daily air quality on adolescent physiological and emotive well-being and emphasize the urgency of developing mitigation strategies to protect students' respiratory health in urban environments.

Comparison with Existing Literature

Our findings are potentially consistent with an expanding literature implicating PM2.5 exposure to paediatric-type respiratory outcomes as a young person. For instance, Xu *et al.* (2021) found that daily PM2.5 levels was associated with increased occurrence of chronic cough and wheezing in schoolchildren, similar to the high symptom rates we found on high pollution days. Similarly, Liu *et al.* (2023) reported a linear dose-response association of particulate exposure with respiratory distress with every additional 10 μg/m³ PM2.5 led to an estimate of approximately 20–30% increase in symptom morbidity, a reasonable correspondence with our fnding of a 1.52 (≈ 52%) increase in odds of symptoms per 10 μg/m³. Wu *et al.* (2023) also illustrate the benefit of behavioral interventions such as consistent mask-wearing and minimizing outdoor activity on high pollution days – thought to reduce severity of respiratory symptoms. This supports our interpretation that protective actions are able to reduce symptomatic days during pollution peaks. It is important to highlight that, as opposed to most previous studies that were based on clinical diagnoses or lung function tests, the data of our study were collected using daily self-reported symptoms as an estimate of health effects. It offers a near-term, practical overview of how pollution affects students on a daily basis in a high-exposure urban environment, to supplement current literature, which tends to focus on long-term or clinically recorded results. By examining short-term variation of pollution, our study takes a novel approach to identify the immediate impact of daily PM2.5 heterogeneity, while the majority of current studies have focused on chronic exposure.

Implications for Public Health and Policy

School-Based Air Pollution Mitigation Strategies

Considering the substantial contribution of high PM2.5 reported in this article impact on student health recorded in this study, schools should consider implementing evidence-based interventions to reduce their students' exposure. School-level strategies that are crucial for such initiatives:

Air Quality Monitoring

Implement real-time PM2.5 sensors, and daily air quality alerts will be shared with the campus. This information can help in making decisions, such as relocating outdoor activities indoors when the level of pollution is high.

Air Filtration Systems

Install HEPA air purifiers (i.e., high-efficiency particulate air purifiers) in classrooms and indoor spaces, particularly during peak-pollution or wildfire seasons, to reduce indoor levels of particulates.

Tailored Outdoor Activity Policies
Modify school schedules and policies so that outdoor athletics and physical education are restricted or rescheduled on days when PM2.5 exceeds unsafe levels (such as >50 $\mu g/m^3$). This can reduce during peak times the exposure of students outdoors to pollution.

Community and Government Action
Wider community and policy-level interventions are also needed to address wider air quality problems, which can impact on schools. Recommended measures include:

Strengthen PM2.5 Regulations
Government agencies need to impose more stringent emissions standards on large sources of pollution (e.g., vehicle, industry, and agriculture burning) in order to lower ambient PM2.5 levels in urban areas. More stringent regulations, and regular monitoring, can limit the number of days with significant pollution.

Raise Awareness for Public Health
Public health education at the community level is necessary to inform students, parents, and school personnel to understand the health effects of PM2.5. Best practices during pollution episodes, such as correct mask wearing and symptom monitoring, that encourage proactive health protection should also be included in these programmes.

Enhance Health Service Accessibility
Schools and local health departments may work together to offer respiratory health checks or medical examinations for students under heavy pollution situations. Better access to healthcare and early intervention (for example, asthma inhalers, medical advice) can reduce the impact of pollution on symptoms of disease.

Promotion of Individual Protective Measures
At the individual level, activating students and their families to engage in protective behaviors can decrease the health effects on the most polluted days:

Mask-Wearing
Recommend or require use of high-efficiency filtration face masks (e.g., N95 masks) by students on days with unhealthy air quality. Our results indicate that sustained mask wearing could drive down reported symptom prevalence by approximately 0.3, a straightforward and effective measure.

Behavioral Modifications
Recommend that students minimize time spent outside during periods of high pollution and discover clean indoor areas, ideally with air filtration, when air pollution is high. The sum of these individual reductions (which a nudging approach could attempt to balance and integrate) could, from nudge-analysis point of view, represent a reduction in the amount of pollution anyone is left to inhale, in the course of a day. Ultimately, a combined strategy targeting all intervention levels – such as school-based projects, government policies, and personal protective measures – can help reduce the respiratory health impacts of air pollution among adolescents in Nonthaburi and other urban locations. An integrated multilevel implementation strategy would maximize the shielding of students from harmful PM2. 5 exposure.

Study Limitations and Future Research Directions
Although providing important clues, the present study had several limitations that need to be taken into account:

Self-Reported Data Bias
The self-report of symptoms (daily Google Form) is the source of some risk of reporting bias or error. Symptoms might be forgotten or reported inconstantly by students, potentially resulting in misclassification. Future studies need to collect an objective health indicator, such as clinical lung function tests or clinical respiratory examination, concurrent with the self-report data to confirm such associations.

Confounding Factors
We did not extensively consider others possible confounders for respiratory symptoms. Symptom reporting on some days may have been influenced by indoor air pollution and previous health (e.g. asthma) and concurrent seasonal respiratory infections (e.g. common colds or flu). These confounders might partially account for differences in health effects regardless of outdoor PM2.5. It would be necessary in future research to adjust for or stratify for such variables possibly by adopting longitudinal study or multivariate analysis to extract the impact of daily PM2.5 more clearly.

Short Study Duration
This analysis focused on a rather narrow exposure window (the months of January–February 2025). This short-term design may miss seasonality, or longer term health effects of prolonged pollution exposure. For example, pollution levels and their respiratory health effects may be different in other seasons (e.g., months of crop-burning or rainy season). Longer term observation over several seasons or a year would lead to a better understanding of the relative influence of chronic and seasonal PM2.5 exposure affects respiratory health in adolescents.

Exposure Data
At the Community Level Daily PM2.5 level were extrapolated from community monitoring stations near the schools and not from personal exposure monitors. This is useful as a general rule of thumb but the actual exposure for individual students can

sometimes differ by micro-environments (home, transit etc.). The lack of individual exposure data suggests the potential for measurement error if a student's immediate area experienced different pollution levels than those reported by the nearest station. Personal air quality sensors are essential, or wearable PM2.5 studies for quantifying individual exposure in a more precise way.

Nevertheless, despite these limitations, the present study presents an important first step toward investigating the acute impact of daily variation in air pollution on adolescent health. It highlights the importance of studying short-term exposure effects, and offers preliminary data to guide larger, better-controlled future studies.

CONCLUSION

This study confirms that daily PM2.5 fluctuations directly affect adolescent respiratory health. In our high school cohort, high-pollution days (>50 μg/m³) were associated with a 27.6% increase in respiratory symptom prevalence compared to cleaner days. We also found a significant correlation between rising PM2.5 levels and worsening respiratory distress ($r = 0.62$, $p < 0.001$), reinforcing evidence that air pollution poses a serious health risk for students. On a positive note, proactive behaviors like mask-wearing proved effective – students who consistently wore masks had markedly lower odds of symptoms (about a 36% risk reduction, OR = 0.64, $p = 0.002$), highlighting the value of personal preventive measures.

Overall, our findings illustrate the acute influence of air quality on youth health and signal that immediate action is needed. Efforts to improve urban air quality – through stricter pollution control policies, school-based air quality management, and community education – are critical for protecting young people in Nonthaburi and other polluted regions. By combining policy interventions with on-the-ground protective strategies, we can better safeguard adolescent health against the day-to-day challenges posed by PM2.5 air pollution.

Recommendations

This study confirms that daily PM2.5 fluctuations significantly affect adolescent respiratory health. Among 132 students in Nonthaburi, symptom prevalence rose by 27.6% on days with PM2.5 >50 μg/m³ compared to low-exposure days (≤25 μg/m³). A strong positive correlation was found between PM2.5 levels and symptom severity ($r = 0.62$, $p < 0.001$). Logistic regression revealed a 52% increase in symptom risk per 10 μg/m³ increase in PM2.5 (OR = 1.52, 95% CI: 1.26–1.79, $p < 0.001$). Mask-wearing reduced symptom likelihood by 36% ($p = 0.002$), highlighting the importance of protective behaviors.

To address these risks, we recommend:

1. Policy Reform – Implement stricter emissions controls and real-time pollution alerts.
2. School-Based Measures – Install air filtration systems and adjust outdoor activities during high-pollution days.
3. Public Awareness – Promote N95 mask use and pollution avoidance behaviors.
4. Further Research – Conduct longitudinal studies with personal exposure tracking and clinical assessments.

These integrated strategies are essential for safeguarding adolescent health in Nonthaburi and similar urban environments facing persistent air pollution challenges.

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