Environ Monit Assess (2020) 192: 646
https://doi.org/10.1007/s10661-020-08605-7

Short-term effect of particular matter and sulfur dioxide exposure on asthma and/or chronic obstructive pulmonary disease hospital admissions in Center of Anatolia

Yeliz Mercan · Ulken Tunga Babaoglu · Arzu Erturk

Received: 24 June 2020 / Accepted: 10 September 2020 / Published online: 17 September 2020

Abstract We investigated the associations between the daily variations of coarse particulate matter (PM_{10}) and/or sulfur dioxide (SO_2) and hospital admissions for asthma and/or chronic obstructive pulmonary disease (COPD) diseases in Kirsehir, Center of Anatolia of Turkey. We analyzed the poison generalized linear model (GLM) to analyze the association between ambient air pollutants such as PM_{10} and SO_2 and asthma and/or COPD admissions. We investigated single-lag days and multi-lag days for the risk increase in asthma, COPD, asthma, and/or COPD hospital admissions PM_{10}, SO_2, and PM_{10} with SO_2 per 10 μg/m^3. In single-lag day model a 10 μg/m^3 increase in the current day (lag 0) concentrations of PM_{10} and SO_2 corresponded to increase of 1.027 (95% CI:1.022–1.033) and 1.069 (95% CI:1.062, 1.077) for asthma. A 10 μg/m^3 increase in the current day (lag 0) concentrations of PM_{10} and SO_2 corresponded to increase of 1.029 (95% CI:1.022–1.035) and 1.065 (95% CI:1.056, 1.075) for COPD. A 10 μg/m^3 increase in the current day (lag 0) concentrations of PM_{10} and SO_2 corresponded to increase of 1.028 (95% CI:1.024–1.032) and 1.068 (95% CI:1.062, 1.074) for asthma and/or COPD. It was found that some lag structures were related with PM_{10} and SO_2. Significant lags were detected in some lag structures from the previous first day until the previous eighth day (lag 1 to lag 7) in the asthma, COPD, and asthma and/or COPD hospital admissions in the model created with PM_{10} with SO_2 both in the single-lag day model and in the multi-lag day model. Our study that used GLM in time series analysis showed that PM_{10} and/or SO_2 short-term exposure in single-lag day and multi-lag day models was related with increased asthma, COPD, and asthma and/or COPD hospital admissions in the city between 2016 and 2019 until the previous-eighth day.

Keywords Asthma · Chronic obstructive pulmonary disease · Particulate matter, Sulfur oxides, Hospital admission · Air pollutants

Y. Mercan
Kirklareli University Health Sciences Institute Department of Public Health, 39000 Kirklareli, Turkey

Y. Mercan (✉)
Kirklareli University School of Health Department of Health Management, 39000 Kirklareli, Turkey
e-mail: mercan.yeliz@gmail.com

U. T. Babaoglu
Kirsehir Ahi Evran University Faculty of Medicine Department of Public Health, 40100 Kirsehir, Turkey
e-mail: ulkentunga@yahoo.com

A. Erturk
Kirsehir Ahi Evran University Faculty of Medicine Department of Chest Diseases, Kirsehir 40100, Turkey
e-mail: arzuerturk@yahoo.com

Introduction

Asthma is usually characterized by chronic airway inflammation, and chronic obstructive pulmonary disease (COPD) is usually characterized by permanent respiratory symptoms and airflow limitation (Hikichi et al. 2018). The asthma-COPD overlap syndrome, which is characterized by persistent airflow limitation, is detected approximately in a quarter of adults with COPD, and in approximately one-third of asthmatic adults (Leung and Sin 2017). It was reported that short- or long-term exposure of PM_{10} and SO_2 causes the development or exacerbation of asthma or COPD, and leads to lung inflammation, oxidative stress, increased respiratory symptoms, effected pulmonary reflexes, reduced lung function, low FEV_1, and FVC (Doiron et al. 2019; Huang et al. 2019; US EPA 2017). This adverse health effect of pollutants causes increases in the respiratory morbidity, respiratory mortality, emergency room visits, or hospitalizations (Sotty et al. 2019; Çapraz et al. 2017; Krall et al. 2018; Rajak and Chattopadhyay 2019). In previous evidence-based studies, it was shown that there is a strong relation between PM_{10} or SO_2 air pollutants and asthma and/or COPD (deMiguel-Díez et al. 2019; Szyszkowicz et al. 2018; Phosri et al. 2019; Pothirat et al. 2019). It was reported in other studies that increases in PM_{10} or SO_2 at a rate of 10 $\mu g/m^3$ could lead to increases in emergency room visits or hospitalizations until the previous-eighth day (from lag 0 to lag 7) (Zheng et al. 2015; Zhang et al. 2016; Gao et al. 2019; Guo and Chen 2018). Studies conducted in Turkey also support the studies, which show that there is a positive relation between PM_{10} or SO_2 exposure and COPD and/or asthma admission (Kara et al. 2013; Saygın et al. 2017).

The 2016 Environmental Status Report in Kirsehir reported increased air pollution between 2011 and 2015 (EUM 2016). The Clean Air Rights Platform reported that one of Kirsehir's border cities was one of the top three cities with the highest air pollution-related deaths in 2018, and air pollution measurements were not made in other cities with the largest border (CARP 2019). In the 2018 Environmental Status Report, it was reported that there were problems related with industrial enterprises, mining activities, traffic, heating, industrial production, and because of the lack of adequate air circulation based on the topographic structure of the city, which is one of the factors that increase the air pollution in Kirsehir (EUM 2019). With these problems that are closely related with Kirsehir, there are no other studies that examine the possible harmful effects of ambient air pollutants on asthma and/or COPD-related hospital admissions. These problems, which constitute a significant part of disease burden and healthcare expenses, remain their importance for public health (Guo and Chen 2018; Niu et al. 2017).

A time-series analysis is often used to explore the link between ambient air pollutants and health outcomes (Guo and Chen 2018; Raji et al. 2020; AlBalawi et al. 2020). We conducted a time-series study of the relationship between daily mean levels of air pollutants (PM_{10}, SO_2, PM_{10} with SO_2) and daily hospital admissions for asthma, COPD, and asthma and/or COPD in Kirsehir, using Poisson regression in a generalized linear model (GLM). In addition, we also analyzed the relation between each pollutant and disease admissions according to single-lag day and multi-lag day models by keeping the time trends and meteorological factors under control.

Materials and methods

Study area

Kirsehir is located in the Central Kizilirmak section of Central Anatolia in Turkey where there is a semi-arid and terrestrial climate feature (38° 50′–39° 50′) (33° 30′–34° 50′). Kirsehir had a population of approximately 243 thousand in 2019, and 7 rural districts in an area of 6570 km^2. Located on the border of the Bozok Plateau, the city contains important water resources such as the Seyfe Lake and the Hirfanli Dam Lake. It has natural borders with Nevsehir, Aksaray, Kirikkale, Yozgat, and Ankara (EUM 2019) (Fig. 1).

Asthma and COPD admissions

The data of the study were obtained from the emergency room, internal medicine clinic, and chest diseases clinic records of Kirsehir Research and Training Hospital between 01 August 2016 and 01 August 2019. The admissions over the age of 18 living in Kirsehir were evaluated. The samples were selected according to the code in International Classification of Diseases (ICD), 10th revision for all patients. In this classification, according to ICD-10, 36,906 people who received any of the J45, J45.0, J45.1, J45.8, and J45.9 diagnostic codes constituted the admissions for asthma; and 23,830 people who received the diagnostic codes of J41–J44 constituted COPD admissions. A total of 710 people were diagnosed with both asthma and COPD. For this reason, asthma and/or COPD admissions were examined separately as total admissions (N = 60.026). In this study, date of admission and diagnostic and residential address data were used. The residential address of the patients

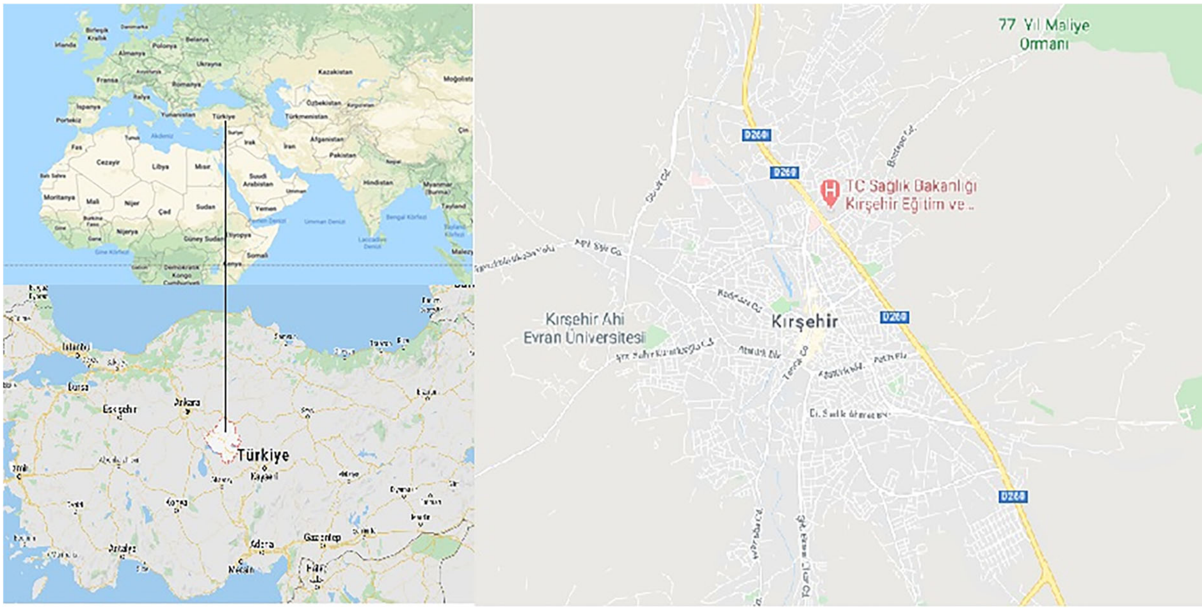

Fig. 1 The geographical location of Kirsehir

with asthma and/or COPD living in the study area were verified. Also, multiple admissions of the same person between the study dates were evaluated as new patients.

Environmental data

Daily 24-h average values for PM_{10} and SO_2 were acquired from the National Air Quality Monitoring (AQM) from 01 August 2016 to 01 August 2019. Daily 24-h average for temperature (°C), relative humidity (%), and atmospheric pressure (hPa) was acquired from the Meteorological Information and Presentation System (MIPS) between the same dates. The daily concentrations were obtained from the available monitoring data of one fixed-site station. The measurements are made on an hourly basis in this station and are released at AQM at https://www.havaizleme.gov.tr/ after verification. The ± 3 moving average method was used in missing measurements of 24-h averages of the PM_{10} and SO_2 measurements.

Statistical analysis

In this study, the relation between daily asthma, COPD, and asthma and/or COPD hospital admissions due to outdoor air pollutants PM_{10} and SO_2 concentration levels and current and lagged days was examined with generalized linear model (GLM) (Çapraz et al. 2017; AlBalawi et al. 2020). The effects of PM_{10}, SO_2, and PM_{10} with SO_2 on the hospital admissions were analyzed separately for single-lag days and multi-lag days (Guo and Chen 2018). The effect of each pollutant concentration in single-day models was included in the model alone for that specific day (lag 0 or lag 1 or lag 2 etc.). In multi-lag day models, the combined effect of the days (from lag 0 to lag 7) was investigated by using the level of concentration of each pollutant. In the study, lag time zero (lag 0) was defined as the same-day exposure to PM_{10}, SO_2, and PM_{10} with SO_2. For instance, a lag 0 means the pollutant concentration effect in current-day, a lag 1 means the concentration in the previous-first day, and a lag 7 means the concentration in previous-eighth day. In addition, the lags between consecutive days were shown as intervals. For example, lags 1–4 refer to the previous-second day, previous-third day, previous-fourth day, and previous-fifth day. Since emergency department admissions were also included in the hospital admissions in the study, the hospital admissions at weekends and on holidays were also included in the analyses. Previous studies considered weather conditions for air pollution as confounding factors that should be controlled (Çapraz et al. 2017; Chen et al. 2019). In our time series, after adjusted for the time trend and temperature, relative humidity, atmospheric pressure time series were included in the model as confounding variables (Qu et al. 2019). Finally, Poisson GLM was applied to the data in order to estimate adjusted relative risk (RR) with 95% CI of the independent variables in the constructed model. The adjusted RRs were estimated with each 10 μg/m^3 increment of PM_{10}, SO_2, and PM_{10} with SO_2. The analysis was performed using the Statistical Package for the Social Sciences, version 22.0 (SPSS Inc., Chicago, IL, USA).

Results

Table 1 summarizes the hospital admission counts and levels of concentration of environmental variables. Daily average patient counts were 34 for asthma admissions, 22 for COPD admissions, and 55 for asthma and/or COPD admissions. Daily average concentrations were 23.7 μg/m^3 for PM_{10} and 9.6 μg/m^3 for SO_2.

Except for the relation between the temperature and relative humidity, in general, air pollution and meteorology parameters had relatively low correlated coefficients with each other (Table 2).

Figure 2 presents the results of single-lag days and multi-lag days for the increase in the risk in asthma, COPD, and asthma and/or COPD hospital admissions PM_{10} and SO_2 per 10 μg/m^3 after adjustment for time trend, temperature, relative humidity, and atmospheric pressure. In single-lag day model, a 10 μg/m^3 increase in the current day (lag 0) concentration of PM_{10} associated with 1.027 (95% CI: 1.022, 1.033), 1.029 (95% CI: 1.022, 1.035), 1.028 (95% CI: 1.024, 1.032), increase of asthma, COPD, and asthma and/or COPD hospital admission. In multi-lag day model, a 10 μg/m^3 increase in the current day (lag 0) concentration of PM_{10} associated with 1.015 (95% CI: 1.008, 1.022), 1.019 (95% CI: 1.010, 1.028), 1.016 (95% CI: 1.011, 1.022), increase of asthma, COPD, and asthma and/or COPD hospital admission. And also, in the models, significant relationships were found for some other lag structures of ambient air pollutants.

A 10 μg/m^3 increase in the current day (lag 0) concentration of SO_2 associated with 1.069 (95% CI: 1.062, 1.077), 1.065 (95% CI: 1.056, 1.075), 1.068 (95% CI: 1.062, 1.074), increase of asthma, COPD, and asthma and/or COPD hospital admission. In single-lag day model, while a PM_{10}'s 10 μg/m^3 increase in some previous-eighth-day lags increased the risk of admission to hospital due to asthma, COPD, and asthma and/or COPD, SO_2's 10 μg/m^3 increases further increased the risk of admission in all lags until previous-eighth day (lags 0–7). In multi-lag day models, asthma admissions were 1.065 (95% CI: 1.051, 1.079) for previous-fourth day (lag 3) for each 10 μg/m^3 in SO_2 concentrations; the COPD admissions were previous-second day (lag 1) 1.037 (95% CI: 1.018, 1.056), and asthma and/or COPD admissions were previous-second day (lag 1) 1.025 (95% CI: 1.013, 1.037). While in single-lag day models, significant relationships were found for all lag structures of ambient air pollutants, in multi-lag day models, significant relationships were found for some other lag structures of ambient air pollutants (Fig. 3).

Figure 4 and Fig. 5 present the results of single-lag days and multi-lag days for the increase in the risk of asthma, COPD, and asthma and/or COPD hospital admission for PM_{10} with SO_2's per 10 μg/m^3 after adjustment for time trend, temperature, relative humidity, and atmospheric pressure. In single-lag day model, it was found that asthma

Table 1 Summary of the statistics of admissions, daily air pollutants, and daily meteorology parameters in Kirsehir

	Mean ± SD	Min.	P(25)	Median	P(75)	Max.
Asthma	34 ± 25	0	3	39	53	104
COPD	22 ± 16	0	3	25	34	64
Asthma and/or COPD	55 ± 39	0	5	65	84	149
Air pollutants concentrations						
PM_{10} (μg/m^3)	23.7 ± 18.4	1.3	11.7	17.9	31.3	177.0
SO_2 (μg/m^3)	9.6 ± 11.9	0.4	3.1	5.5	11.0	131.5
Meteorology parameter concentrations						
Temperature (°C)	12.9 ± 9.2	− 11.0	5.6	12.3	20.7	31.0
Relative humidity (%)	58.6 ± 16.7	15.7	45.6	58.3	72.2	95.4
Atmospheric pressure (hPa)	900.4 ± 4.5	884.5	897.3	900.3	903.4	915.0

24-h average for PM_{10}, SO_2, temperature, relative humidity, and atmospheric pressure

Table 2 Correlation coefficients between daily air pollutants and daily meteorology parameters concentrations in Kirsehir

	PM_{10}	SO_2	Temperature	Relative humidity	Atmospheric pressure
PM_{10}	1.00				
SO_2	0.30*	1.00			
Temperature	− 0.02	− 0.59*	1.00		
Relative humidity	− 0.09*	0.38*	− 0.76*	1.00	
Atmospheric pressure	0.14*	0.21*	− 0.37*	0.11*	1.00

*Statistical significance level (two-tailed) < 0.01

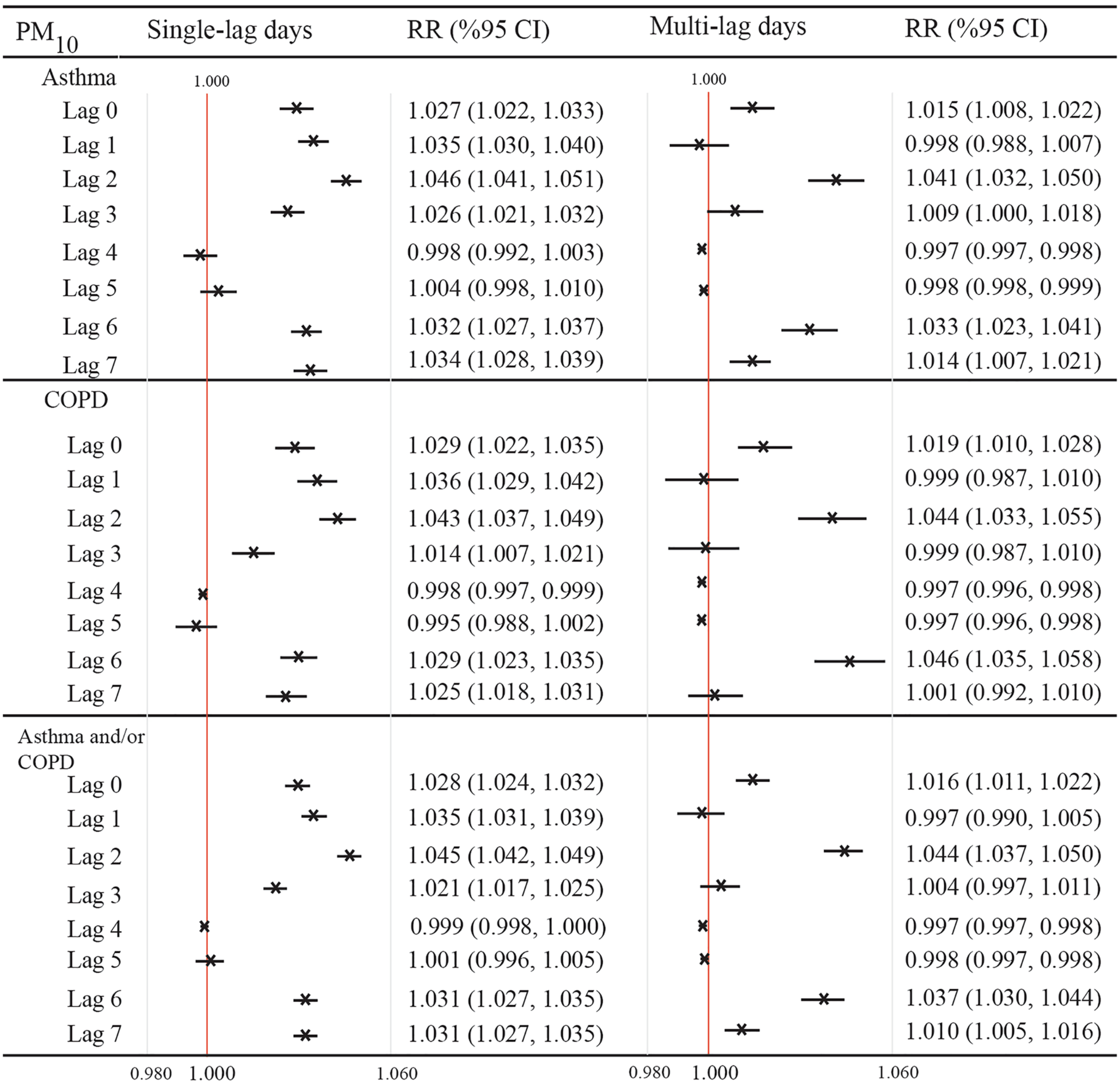

Fig. 2 Relative risk (RR) increase (95% CI) of asthma, COPD, and asthma and/or COPD hospital admissions, associated with 10 μg/m^3 increase of PM_{10} concentrations

hospital admission risk for current day (lag 0) 1.014 (95% CI: 1.008, 1.019) for PM_{10} in each 10 μg/m^3 increase, and 1.063 (95% CI: 1.055, 1.071) for SO_2. COPD hospital admission risks in PM_{10} or SO_2's 10 μg/m^3 increases were 1.016 (95% CI: 1.009, 1.023) and 1.057 (95% CI: 1.048, 1.067), respectively; and the asthma and/or COPD hospital admission risks were 1.015 (95% CI: 1.010, 1.019) and 1.061 (95% CI: 1.055, 1.067), respectively. In exposure to PM_{10}, while hospital admissions responded to some lags until previous-eight-day, the respond of the admissions in exposure to SO_2 was found to be significant at all lags (lags 0–7). In multi lag day model, while the risk of asthma hospital admission risk on current day (lag 0) was 1.011 (95% CI: 1.003, 1.019) at 10 μg/m^3 increase of PM_{10}, for SO_2, this risk was (lag 3) 1.061 (95% CI: 1.045, 1.076) on previous-fourth day. The COPD hospital admission risks for were 1.015 (95% CI: 1.005, 1.025) of PM_{10}'s 10 μ/gm^3 increase on current day (lag 0); for SO_2, this risk was 1.035 (95% CI: 1.015, 1.055) on previous-second day (lag 1). The asthma and/or COPD hospital admission risks were 1.012 (95% CI: 1.006, 1.018) on current day (lag 0) at 10 μg/m^3 increase of PM_{10}; for SO_2, this risk was 1.024 (95% CI:

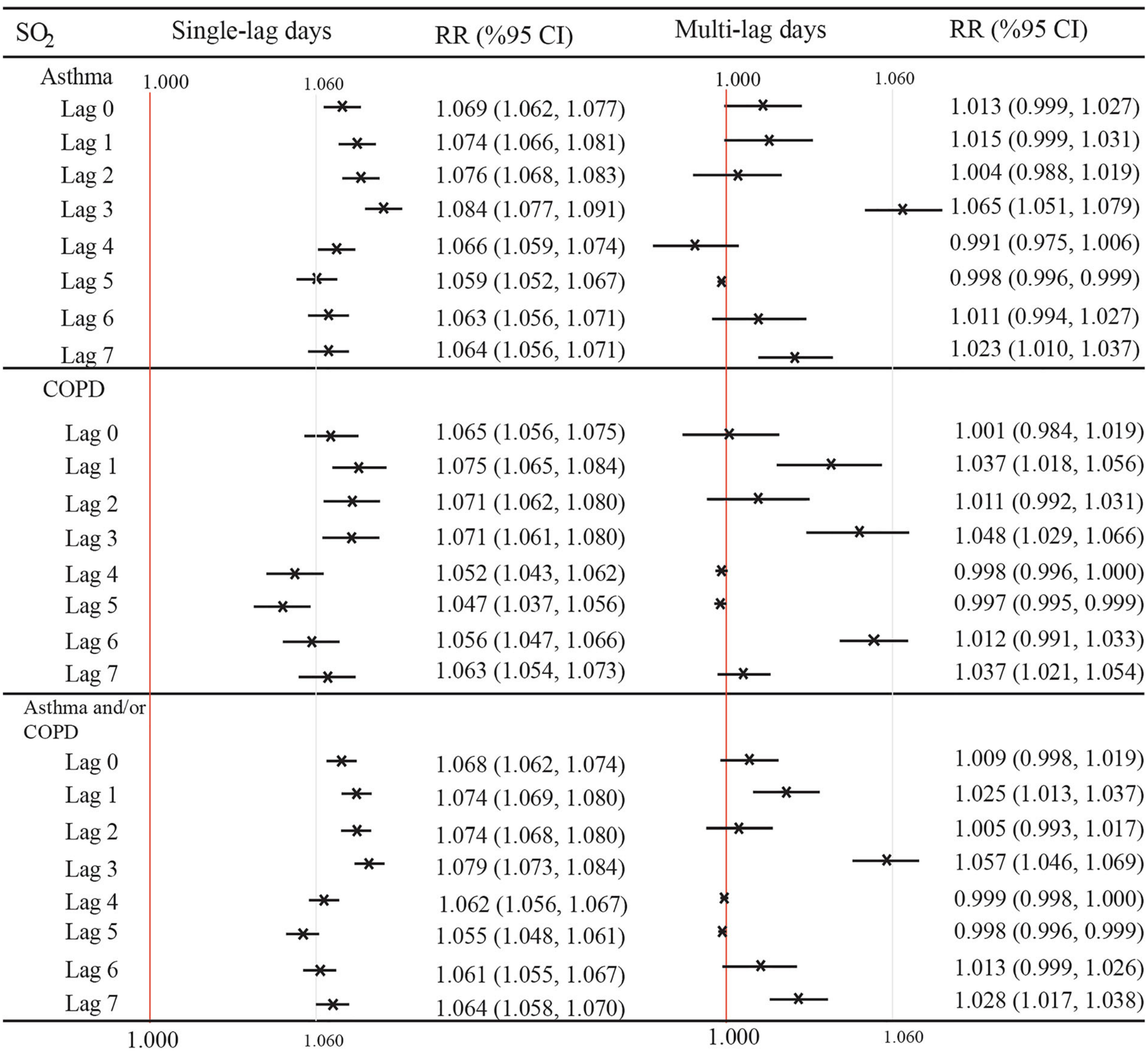

Fig. 3 Relative risk (RR) increase (95% CI) of asthma, COPD, and asthma and/or COPD hospital admissions, associated with 10 μg/m^3 increase of SO_2 concentrations

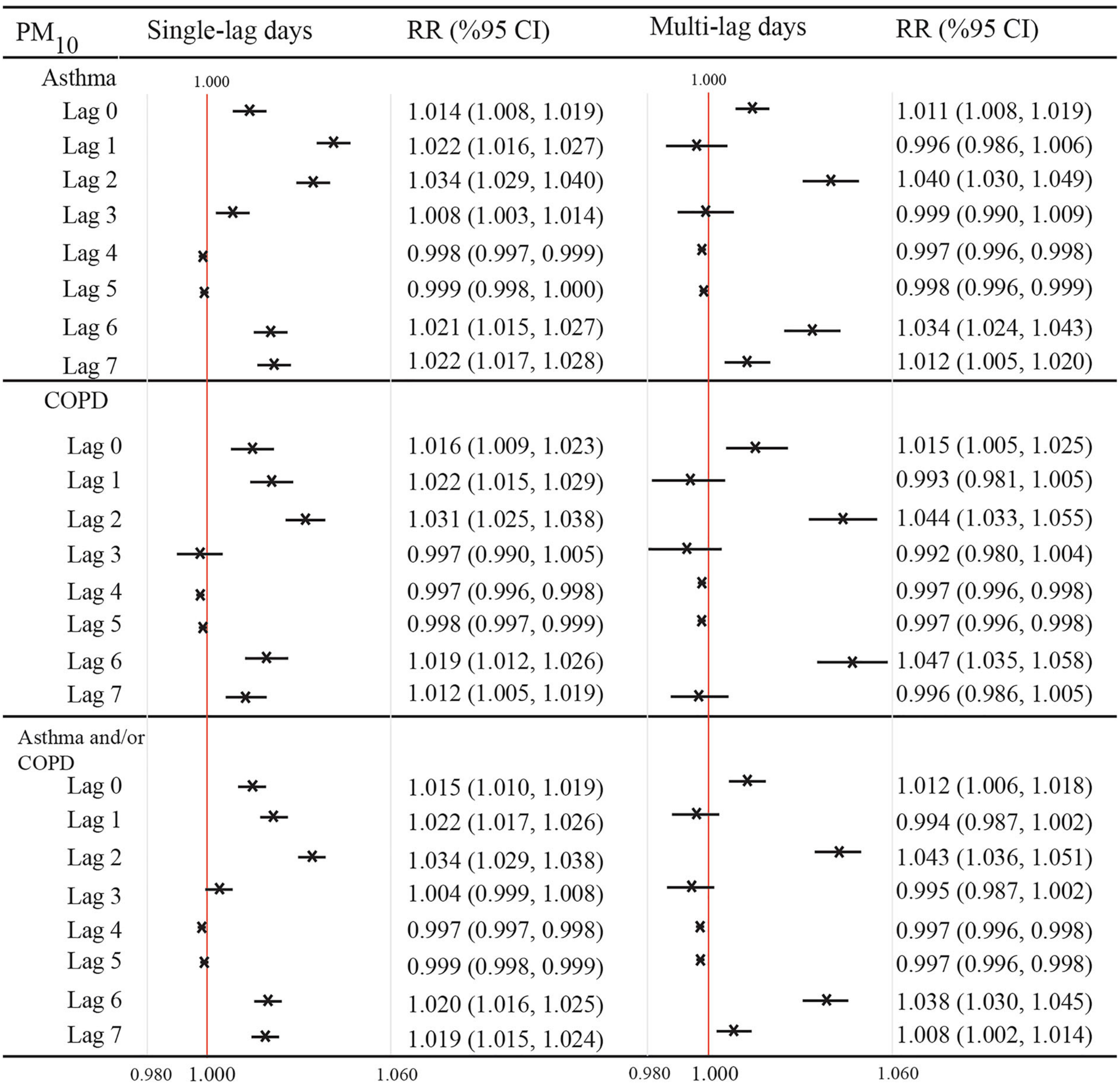

Fig. 4 Relative risk (RR) increase (95% CI) of asthma, COPD, and asthma and/or COPD hospital admissions, associated with 10 μg/m^3 increase of PM_{10} concentrations for PM_{10} with SO_2

1.011, 1.036) on previous-second day (lag 1). Significant relationships were found for some other lag structures of ambient air pollutants.

Discussion

This time series study, which included the 2016–2019 years, showed that PM_{10} and SO_2 air pollutants are related closely with asthma and/or COPD hospital admissions, and cause increased burden on hospital admissions as a result of disease burden in Kirsehir, the rural city of Turkey. In the present study, it was found that asthma, COPD, and asthma and/or COPD hospital admissions were significant in 10 μg/m^3 increases in PM_{10} in most lags in the single-lag day model from current day until previous-eighth day (from lag 0 to lag 7). It was observed that the responses to PM_{10} in multi-lag day model were realized for asthma and asthma and/or COPD admission until previous-fourth day (lag 3), and COPD admissions until the previous-eighth day (lag 7). In previous studies, it was shown that PM_{10} has positive relations with asthma or COPD (Rajak and Chattopadhyay

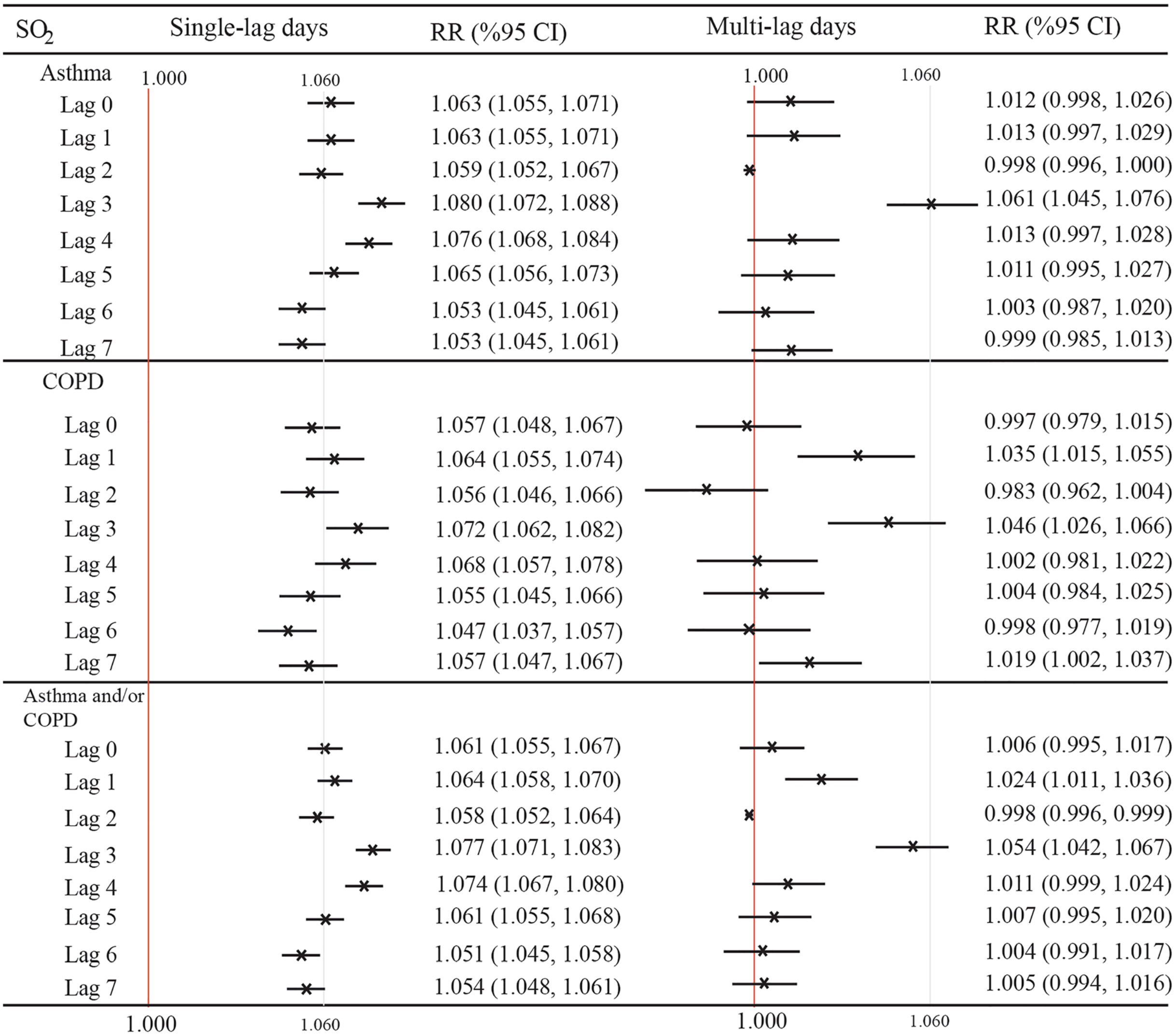

Fig. 5 Relative risk (RR) increase (95% CI) of asthma, COPD, and asthma and/or COPD hospital admissions, associated with 10 μg/m^3 increase of SO_2 concentrations for PM_{10} with SO_2

2019; Krall et al. 2018; Raji et al. 2020; Qu et al. 2019; Saygın et al. 2017). In studies conducted in China (Guo and Chen 2018) and in Saudi Arabia (AlBalawi et al. 2020), it was found that 10 μg/m^3 increases of PM_{10} increased daily asthma patient visits on current day (lag 0) or on 2 days (lag 1 or lag 01). In Thailand, on the other hand, the COPD emergency visit risk increase in 10 μg/m^3 increases of PM_{10} responded until the previous-second day (lags 0–1), and hospitalization risk increase responded on the previous-fourth day (lag 3) (Pothirat et al. 2019). In another study, it was found that the cumulative lag effect with the increase of COPD hospital visits in PM_{10} 10 μg/m^3 was significant in all lags (lag 0–6) until the previous-seventh day (Gao et al. 2019). In meta-analytical studies, 10 μg/m^3 increases of PM_{10} were associated with significant increases in lags of asthma or COPD emergency room visits and hospitalization risks on previous-second day or more (Zheng et al. 2015; Zhang et al. 2016). It is already known that there are high emission rates and traffic problems in Kirsehir (EUM 2019), and the size and content of PM cause pathologies occurring in the airway and exacerbate asthma or COPD (Wagner et al. 2012; Feretti et al. 2019; Zheng et al. 2015; Sotty et al. 2019). In the UK Biobank study, a significant relation was found between $PM_{2.5}$ per 5 μg/m^3 increase and low FEV_1 and FVC capacity; and 1.52-time increase was reported for $PM_{2.5}$ of COPD prevalence, and 1.08-time for PM_{10} (Doiron et al. 2019). In our time series in which more lags were detected compared with previous studies, it is considered that the increases associated with pollution reasons reported in the city might have been caused by the effect of other pollutants caused by PM_{10} content.

In our study, SO_2's 10 μg/m^3 increases responded to all lags (lags 0–7) until previous-eighth day in COPD, and asthma and/or COPD hospital admissions in single-lag day model, and responded to some lags in multi-lag day model (from lag 0 to lag 7). In previous studies, it was found that the asthma-associated hospital or emergency room admissions in 10 μg/m^3 increases of SO_2 were significant in some lags until previous-fourth day (lag 4) (Raji et al. 2020; AlBalawi et al. 2020; Chen et al. 2019). Guo and Chen (2018) showed that asthma admissions increased at a rate of 1.08–3.79% during the previous-seven days (lags 0–6) in 10 μg/m^3 increases of SO_2. In a meta-analysis study, it was found that COPD general and emergency hospital admissions in SO_2 exposure had 1.007–1.011-time higher risk (Zhang et al. 2016). In addition, in this analysis of ours, it was observed that the single-lag day model responded to more lags compared with the multi-lag day model. It was showed in a previous study that the cumulative lag effect of SO_2's 10 μg/m^3 increases increased the COPD hospital visit risk until the first 2 days (lags 0–1), and until the eighth day in hot season (except for lag 2, lags 0–7) (Gao et al. 2019). In our study, it was found that the SO_2 level exceeded the limit value (20 μg/m^3) (WHO 2006) in the World Health Organization Air Quality Guide at high levels until approximately one-eighth of the time series and until six times, which was associated with the hollow topography of the city and inadequate air circulation. In addition, the presence of the emissions of industrial activities and the problems caused by heating (low-quality coal use, inadequate education etc.) explained the significant and strong increases in the lags (EUM 2019). In a previous study conducted in Turkey, it was found that the total asthma cases that were reported between 2008 and 2010 were highly associated with high SO_2 concentrations (Kara et al. 2013).

In our study, in Fig. 4 and Fig. 5, which examined the effect of PM_{10} with SO_2 on asthma, COPD, and asthma and/or COPD hospital admissions, the risk of hospital admission in PM_{10} and SO_2's 10 μg/m^3 increases responded to many lags in single-lag day and multi-lag day models until the previous-eighth day. It was found that the single-lag day model was stronger than the multi-lag day model. In a previous study, although no relations were detected between asthma admissions and lags in single-pollutant models created with PM_{10} with SO_2 and $PM_{2.5}$ with SO_2, the risk increased significantly in multi-pollutant models created with PM_{10}, O_3, and NO_2 (Guo and Chen 2018). In a study conducted in Australian women cohort, it was found that there were no significant differences between pollutants and adult asthma; however, the COPD risk was 1.019–1.025-time higher when PM_{10} and SO_2 were modeled alone, or with CO, NOx, and $PM_{2.5}$ (Hendryx et al. 2019). In a study, it was also found that 9.4% of the COPD hospitalizations stemmed from PM_{10}, and 1.7% stemmed from SO_2 (Qu et al. 2019). It was found in one of previous studies that the cumulative lag effect of COPD hospital visits was strong in multiday models created with $PM_{2.5}$, PM_{10}, NO_2, SO_2, and CO. In this model, the cumulative lag effect of 10 μg/m^3 increase of PM_{10} responded to the lags on the previous-eighth day (lag 07), and to the lags on the previous-second day (lag 01) in 10 μg/m^3 increase of SO_2 (Gao et al. 2019). Several potential factors contribute to heterogeneity in air pollution. The problems caused by air pollution in the border neighbors of Kirsehir, which is a developing city in Turkey (CARP 2019), might contribute more in addition to the existing air pollution. These findings in which the risk levels of pollutants on disease were found to be different in previous studies can be defined with the socio-demographic status of local people, current disease problems, human behaviors, and the urban transformation activities in the city.

The present study had some strength. Firstly, it is the first study in Kirsehir that examines asthma and/or COPD hospital admission and provided scientific literature on the effects of air pollution on health. Also, the relation of asthma and/or COPD hospital admissions with PM_{10}, SO_2, and PM_{10} with SO_2 was investigated until the previous-eighth day in the study in single-lag day and multi-lag day models, which were created with GLM models. Finally, this study was conducted by using a population that could be a good representation of the whole population in the study area. Briefly, our study proved that the relation between PM_{10}, SO_2, and PM_{10} with SO_2 and hospital admissions is comparable with previous studies.

It should also be mentioned that the present study also had some limitations. Because of the fact that measurements are not made for other pollutants (PM2.5, O3, CO, NO2 etc.) among air pollution parameters in Kirsehir, the hospital applications that stemmed from other pollutants could not be investigated. Also, the fact that the measurements were made in a single station in the city center prevented the detection of real exposures of residents in remote areas or in places where the pollution is intense. The fact that the behavioral characteristics of people admitted to hospitals like age, gender, socioeconomic characteristics, or smoking status were not known prevented the clear detection of real effects of sensitive groups. In addition, it may not be generalized to society due to the fact that the study population consists of hospital admissions.

Conclusions

As a conclusion, our study, which was conducted by using GLM in time series analysis, showed that PM_{10} or SO2 exposure on single and multi-lag day models was associated with increased asthma, COPD, and asthma and/or COPD hospital admissions until the previous-eighth day in the city between 2016 and 2019. This result can be seen as the reason of increasing asthma and/or COPD disease burden in Kirsehir, Center of Anatolia of Turkey.

Local authorities can be informed about the results of the present study, and in this way, preventive measures can be taken to improve public health. The actual pollution levels in the city can be determined by increasing the number of air pollution measurement stations. In this way, the effects of air pollutants on the burden of disease or admissions to hospitals can be clearly identified. The awareness of the community on air pollution can be increased, and especially sensitive groups can be trained to avoid leaving the house or take personal protection measures on intense times of pollution.

Acknowledgments The authors would like to acknowledge Yilmaz Mercan (MSc) for their valuable insights into the design and application of the graphics of this work.

Compliance with ethical standards

Permission for the study was received from Kirsehir Ahi Evran Training and Research Hospital (Date: 24.10.2019, Decision No: 42884709-806.99). Ethical Approval was obtained from the Ethics Board of Clinical Research at Kirsehir Ahi Evran University (Date: 24.09.2019 and Decision No: 2019-16/168).

Conflict of interest The authors declare that they have no conflict of interest.

References

AlBalawi, S. M., Namdeo, A., Hodgson, S., Pless-Mulloli, T., & McNally, R. J. Q. (2020). Short-term effects of air pollution on daily asthma-related emergency department visits in an industrial city. *Journal of Public Health (Oxford, England)*. https://doi.org/10.1093/pubmed/fdaa035.

Clean Air Rights Platform (CARP) (2019). Air pollution and health effects black report. https://www.temizhavahakki.com/kara-rapor/ Accessed 15 April 2020.

Çapraz, Ö., Deniz, A., & Doğan, N. (2017). Effects of air pollution on respiratory hospital admissions in İstanbul, Turkey, 2013 to 2015. *Chemosphere., 181*, 544–550. https://doi.org/10.1016/j.chemosphere.2017.04.105.

Chen, J., Jiang, X., Shi, C., Liu, R., Lu, R., & Zhang, L. (2019). Association between gaseous pollutants and emergency ambulance dispatches for asthma in Chengdu, China: a time-stratified case-crossover study. *Environmental Health and Preventive Medicine, 24*(1), 20. https://doi.org/10.1186/s12199-019-0773-0.

deMiguel-Díez, J., Hernández-Vázquez, J., López-de-Andrés, A., Álvaro-Meca, A., Hernández-Barrera, V., & Jiménez-García, R. (2019). Analysis of environmental risk factors for chronic obstructive pulmonary disease exacerbation: a case-crossover study (2004-2013). *PLoS One, 14*(5), e0217143. https://doi.org/10.1371/journal.pone.0217143.

Doiron, D., de Hoogh, K., Probst-Hensch, N., Fortier, I., Cai, Y., De Matteis, S., & Hansell, A. L. (2019). Air pollution, lung function and COPD: results from the population-based UK Biobank study. *The European Respiratory Journal, 54*(1), 1802140. https://doi.org/10.1183/13993003.02140-2018.

Environment and Urban Ministry (EUM) (2016). *Environmental status report for Turkey.* https://webdosya.csb.gov.tr/db/ced/editordosya/tcdr_ing_2015.pdf Accessed date: 20 January 2020.

Environment and Urban Ministry (EUM) (2019). *Kirsehir Province 2018 environmental status report*. https://webdosya.csb.gov.tr/db/ced/icerikler/kirseh-r_2018_-cdr_son-20191024100156.pdf Accessed 18 January 2020.

United States Environmental Protection Agency (US EPA) (2017). *Integrated science assessment for sulfur oxides – health criteria.* https://www.epa.gov/isa/integrated-science-assessment-isa-sulfur-oxides-health-criteria Accessed 05 February 2020.

Feretti, D., Pedrazzani, R., Ceretti, E., Dal Grande, M., Zerbini, I., Viola, G. C. V., Gelatti, U., Donato, F., & Zani, C. (2019). "Risk is in the air": polycyclic aromatic hydrocarbons, metals and mutagenicity of atmospheric particulate matter in a town of Northern Italy (Respira study). *Mutation Research, 842*, 35–49. https://doi.org/10.1016/j.mrgentox.2018.11.002.

Gao, N., Li, C., Ji, J., Yang, Y., Wang, S., Tian, X., & Xu, K. F. (2019). Short-term effects of ambient air pollution on chronic obstructive pulmonary disease admissions in Beijing, China (2013-2017). *International Journal of Chronic Obstructive Pulmonary Disease, 14*, 297–309. https://doi.org/10.2147/COPD.S188900.

Guo, H., & Chen, M. (2018). Short-term effect of air pollution on asthma patient visits in Shanghai area and assessment of economic costs. *Ecotoxicology and Environmental Safety, 161*, 184–189. https://doi.org/10.1016/j.ecoenv.2018.05.089.

Hendryx, M., Luo, J., Chojenta, C., & Byles, J. E. (2019). Air pollution exposures from multiple point sources and risk of incident chronic obstructive pulmonary disease (COPD) and asthma. *Environmental Research, 179*(Pt A), 108783. https://doi.org/10.1016/j.envres.2019.108783.

Hikichi, M., Hashimoto, S., & Gon, Y. (2018). Asthma and COPD overlap pathophysiology of ACO. *Allergology International, 67*(2), 179–186. https://doi.org/10.1016/j.alit.2018.01.001.

Huang, K., Shi, C. M., Min, J. Q., Li, L., Zhu, T., Yu, H., & Deng, H. (2019). Study on the mechanism of curcumin regulating lung injury induced by outdoor fine particulate matter (PM2.5). *Mediators of Inflammation, 2019*, 8613523. https://doi.org/10.1155/2019/8613523.

Kara, E., Özdilek, H. G., & Kara, E. E. (2013). Ambient air quality and asthma cases in Niğde, Turkey. *Environmental Science and Pollution Research International, 20*(6), 4225–4234. https://doi.org/10.1007/s11356-012-1376-0.

Krall, J. R., Chang, H. H., Waller, L. A., Mulholland, J. A., Winquist, A., Talbott, E. O., Rager, J. R., Tolbert, P. E., & Sarnat, S. E. (2018). A multicity study of air pollution and cardiorespiratory emergency department visits: comparing approaches for combining estimates across cities. *Environment International, 120*, 312–320. https://doi.org/10.1016/j.envint.2018.07.033.

Leung, J. M., & Sin, D. D. (2017). Asthma-COPD overlap syndrome: pathogenesis, clinical features, and therapeutic targets. *BMJ., 358*, j3772. https://doi.org/10.1136/bmj.j3772.

Niu, Y., Chen, R., & Kan, H. (2017). Air pollution, disease burden, and health economic loss in China. *Advances in Experimental Medicine and Biology, 1017*, 233–242. https://doi.org/10.1007/978-981-10-5657-4_10.

Phosri, A., Ueda, K., Phung, V. L. H., Tawatsupa, B., Honda, A., & Takano, H. (2019). Effects of ambient air pollution on daily hospital admissions for respiratory and cardiovascular diseases in Bangkok, Thailand. *Science of the Total Environment, 651*(Pt 1), 1144–1153. https://doi.org/10.1016/j.scitotenv.2018.09.183.

Pothirat, C., Chaiwong, W., Liwsrisakun, C., Bumroongkit, C., Deesomchok, A., Theerakittikul, T., Limsukon, A., Tajarernmuang, P., & Phetsuk, N. (2019). Acute effects of air pollutants on daily mortality and hospitalizations due to cardiovascular and respiratory diseases. *Journal of Thoracic Disease, 11*(7), 3070–3083. https://doi.org/10.21037/jtd.2019.07.37.

Qu, F., Liu, F., Zhang, H., Chao, L., Guan, J., Li, R., Yu, F., & Yan, X. (2019). The hospitalization attributable burden of acute exacerbations of chronic obstructive pulmonary disease due to ambient air pollution in Shijiazhuang, China. *Environmental Science and Pollution Research International, 26*(30), 30866–30875. https://doi.org/10.1007/s11356-019-06244-1.

Raji, H., Riahi, A., Borsi, S. H., Masoumi, K., Khanjani, N., AhmadiAngali, K., Goudarzi, G., & Dastoorpoor, M. (2020). Acute effects of air pollution on hospital admissions for asthma, COPD, and bronchiectasis in Ahvaz, Iran. *International Journal of Chronic Obstructive Pulmonary Disease, 15*, 501–514. https://doi.org/10.2147/COPD.S231317.

Rajak, R., & Chattopadhyay, A. (2019). Short and long-term exposure to ambient air pollution and impact on health in India: a systematic review. *International Journal of Environmental Health Research*, 1–25. https://doi.org/10.1080/09603123.2019.1612042.

Sotty, J., Garçon, G., Denayer, F. O., Alleman, L. Y., Saleh, Y., Perdrix, E., Riffault, V., Dubot, P., Lo-Guidice, J. M., & Canivet, L. (2019). Toxicological effects of ambient fine (PM2.5-0.18) and ultrafine (PM0.18) particles in healthy and diseased 3D organo-typic mucocilary-phenotype models. *Environmental Research, 176*, 108538. https://doi.org/10.1016/j.envres.2019.108538.

Saygın, M., Gonca, T., Öztürk, Ö., Has, M., Çalışkan, S., Has, Z. G., & Akkaya, A. (2017). To investigate the effects of air pollution (PM10 and SO2) on the respiratory diseases asthma and chronic obstructive pulmonary disease. *Turkish Thoracic Journal, 18*(2), 33–39. https://doi.org/10.5152/TurkThoracJ.2017.16016.

Szyszkowicz, M., Kousha, T., Castner, J., & Dales, R. (2018). Air pollution and emergency department visits for respiratory diseases: a multi-city case crossover study. *Environmental Research, 163*, 263–269. https://doi.org/10.1016/j.envres.2018.01.043.

Wagner, J. G., Morishita, M., Keeler, G. J., & Harkema, J. R. (2012). Divergent effects of urban particulate air pollution on allergic airway responses in experimental asthma: a comparison of field exposure studies. *Environmental Health, 11*, 45. https://doi.org/10.1186/1476-069X-11-45.

World Health Organization (WHO) (2006). Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide Global update 2005 Summary of risk assessment. https://apps.who.int/iris/bitstream/handle/10665/69477/WHO_SDE_PHE_OEH_06.02_eng.pdf?sequence=1&isAllowed=y Accessed 01 February 2020.

Zhang, S., Li, G., Tian, L., Guo, Q., & Pan, X. (2016). Short-term exposure to air pollution and morbidity of COPD and asthma in East Asian area: a systematic review and meta-analysis. *Environmental Research, 148*, 15–23. https://doi.org/10.1016/j.envres.2016.03.008.

Zheng, X. Y., Ding, H., Jiang, L. N., Chen, S. W., Zheng, J. P., Qiu, M., Zhou, Y. X., Chen, Q., & Guan, W. J. (2015). Association between air pollutants and asthma emergency room visits and hospital admissions in time series studies: a systematic review and meta-analysis. *PLoS One, 10*(9), e0138146. https://doi.org/10.1371/journal.pone.0138146.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.