Impact of Short-Term Exposure to Below Recommended PM₁₀ Pollution Levels on Asthma Exacerbations

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Air pollution significantly affects health, causing up to 7 million premature deaths annually with an even larger number of hospitalizations and days of sick leave [1]. The negative impact of pollutants on human health is well known. Several epidemiological studies have observed positive associations between exposure to particulate matter (PM) and morbidity and mortality for obstructive pulmonary diseases, including asthma [2-3]. Although there is well-documented evidence that short-term exposures to PM_{10}, Ozone or NO_2, contribute to asthma exacerbations [4], no threshold for PM_{10} concentrations has been established below the maximum recommended by World Health Organization (WHO)[5]. This study aims to analyse the levels and time of exposure from which exposure to PM_{10} can have an impact in asthmatic patients, who visited the Emergency Department (ED) with an exacerbation of their asthma.

We have conducted a retrospective, observational cohort-study, using data collected at the ED of La Paz University Hospital, Madrid, Spain, from January 1st to December 31st, 2014. This hospital is a tertiary referral centre for a population of 500,000 in northern Madrid. Specific search, enrolment and data collection have been published elsewhere [6], but in summary, 831 patients, aged >14 years, who attended the ED with an asthma exacerbation, were enrolled. For each event, 84 variables were identified for data collection, considering patient characteristics both in epidemiological and comorbid conditions, according to the consensus criteria of the 2009 Spanish guideline on asthma management (GEMA-2009) [7]. The study was approved by the local ethics committee, and permission was obtained for the use of confidential data.

PM_{10} hourly concentrations were collected from three different stations (Cuatro Caminos, Paseo de la Castellana and Plaza de Castilla) covering the hospital influence area, from the institutional database of the Madrid City Council, from December 28th, 2013 to December 31st, 2014 [8]. PM_{10} hourly data was measured with a heated tapered oscillating microbalance (TEOM). Average hourly concentrations were calculated using the hourly

concentration of the referred measurement stations. PM_{10} concentrations were considered from 10 μg/m^3 to 40 μg/m^3, and exposure times from 4h to 16h, in 2 hours intervals, for a two-day lag to each individual ED visit. In order to validate the procedure, 11,025 models have been examined, considering different PM_{10} levels and times of exposure for each patient, establishing a significance level of 95%. The parameters of the models were estimated using both maximum likelihood estimators and a boot strap system (50 replications); we could observe that both models converged with the same results (figure 2. supplementary files).

The association between different PM_{10} pollution levels, exposure times and asthma episodes were studied using a logistic model for binary outcomes and both continuous and binary independent variables. The independent variables of the model were age, gender and a binary variable that explain the level of exposure to PM_{10} pollutants for a 2-day lag prior to the ED visit. The initial data processing to build the model was performed using the software MATLAB-R2020, while the models were developed using the STATA-V24 statistical package. The outcome of the analysis was the probability of an asthma exacerbation in asthmatic patients who visited the ED.

According to the model results, (figure 1), if there is a PM_{10} concentration of 22 ug/m^3 for a 10-hour period the day prior to the ED visit, and a PM_{10} level of between 14 ug/m^3 and 30 ug/m3 for a 10-hour period two days prior to the visit, (see blue line), there is a moderate probability of suffering an asthma exacerbation (within 0.18-0.26, $p<0.05$). When the PM_{10} concentration and exposure time is increased, (38 μg/m^3 for 16 hours the day prior to the ED visit and a PM_{10} level between 26 ug/m^3 and 30 ug/m^3 for 16 hours two days prior the ED visit), the probability for having an asthma exacerbation rises to 48%.

In the real world, dynamic changes in air pollutants and meteorological factors coexist simultaneously [9]. Age, temperature, allergen concentrations, and many other pollutants play a role in increasing or decreasing the risk of an exacerbation in asthmatics [10] but it is not clearly established how PM_{10} affects it. A recent meta-analysis has concluded that a 10 μg/m3 increase in PM_{10} acute exposure was associated with a -0.19L/min (95%CI: -0.30; -

0.09) change in peak expiratory flow, particularly among non-smoker asthmatics [11]. We cannot offer any lung-function data because they were not recorded at the clinical charts, but, globally, our study has found positive association between PM_{10} and visits to ED due to asthma exacerbation. Previous studies provided consistent conclusions that elevating concentrations of PM10 was associated with more asthma attacks. Similarly, a 10 μg/m^3 increase in PM_{10} concentration was strongly associated to a higher risk of respiratory outpatient visits with the highest effect noted on lag day of 2 [12]. Unfortunately, our study is retrospective and it is difficult to obtain a precise probability to suffer an asthmatic exacerbation because it is really unknown if a single patient has been or not exposed. Moreover, we could not explore the associations between daily variations in meteorological factors which could influence our results [13,10]. However, its major strength is that the model had analysed the impact of PM^{10} on each patient with an exacerbation, in a comparative scenario, taking into account their individual characteristics and different levels of PM_{10} concentration and time of exposure.

We have identified the maximum risk for PM_{10} levels to be above 38 μg/m^3 with an exposure time >16 hours, which consistent with previous reports [14-15]. However, this study confirms the hypothesis that the exposure to PM_{10} at levels below those established by WHO could also be dangerous for health and increase the probability to visit the ED with an asthma exacerbation.

In summary, although high levels and longer times of exposure to PM_{10} are clearly associated with the worsening of asthma, exposure to PM_{10} even lower concentrations than previously recommended could also increase the risk of asthma exacerbations. Further evidence in well-designed studies is required to definitively establish a safe threshold for this pollutant in asthmatic patients.

Conflicts of interest

All the authors declare no conflict of interest for this manuscript.

Financial sources

References

1. D 'Amato M, Cecchi L, Annesi-Maesano, I, D'Amato G. News on Climate Change, Air Pollution, and Allergic Triggers of Asthma.J Invest Allergol Clin Immunol, 2018; 28(2):91-97.

2. Dávila I, Mullol J, Bartra J, Del Cuvillo A, Ferrer M, Jaúregui I, et al. Effect of pollutants upon patients with respiratory allergies. J Invest Allergol Clin Immunol 2007; 17 (Suppl 2):9-20.

3. Chang Q, Liu S, Chen Z, Zu B, Zhang H. Association between air pollutants and outpatient and emergency hospital visits for childhood asthma in Shenyang city of China. Int J Biometeorol. 2020;64:1539-48

4. Liu Y, Pan J, Zhang H, Shi C, Li G, Peng Z, et al. Short-Term Exposure to Ambient Air Pollution and Asthma Mortality. Am J RespirCrit Care Med. 2019; 200:24-32

5. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide [Internet]. World Health Organization: 2006 [Cited 2020 Dec 11]. Available from:

   https://apps.who.int/iris/bitstream/handle/10665/69477/WHO_SDE_PHE_OEH_06.02_eng.pdf?sequence=1

6. Pola-Bibian B, Dominguez-Ortega J, Vilà-Nadal G, Entrala A, González-Cavero L, Barranco P, et al. Asthma exacerbations in a tertiary hospital: Clinical features, triggers, and risk factors for hospitalization. J Invest Allergol Clin Immunol.2017; 27:238-45

7. Executive Committee GEMA 2009. GEMA 2009: Spanish guideline on the management of asthma. J Invest Allergol Clin Immunol. 2010; 20 (Suppl 1):1-59.

8. Calidad del aire. Datos en tiempo real. [Internet]. Portal de los datos abiertos del Ayuntamiento de Madrid. [Cited 2020 Jul 10]. Available from: https://datos.madrid.es/portal/site/egob/menuitem.c05c1f754a33a9fbe4b2e4b284f1a5a0/?vgnextoid=41e01e007c9db410VgnVCM2000000c205a0aRCRD&vgnextchannel=374512b9ace9f310VgnVCM100000171f5a0aRCRD

9. Cabrera M, Garzón García B, Moreno Grau S, Subiza J. Association between seasonal allergic rhinitis and air pollution, meteorological factors, and grass pollen counts in Madrid (1996 and 2009). J Invest Allergol Clin Immunol 2019; 29:371-7

10. Yu H, Lin CR, Tsai J, Hsieh Y, Tsai T, Tsai C, et al. A multifactorial evaluation of the effects of air pollution and meteorological factors on asthma exacerbations. Int J Environ Res Public Health. 2020; 17:4010.

Supplementary References

11. Edginton S, O'Sullivan DE, King WD, Lougheed MD. The effect of acute outdoor air pollution on peak expiratory flow in individuals with asthma: A systematic review and meta-analysis. Environ Res. 2021;192: 110296

12. Ma Y, Xiao B, Liu C et al. Association between ambient air pollution and emergency room visits for respiratory diseases in spring dust storm season in Lanzhou, China. Int J Environ Res Public Health 2016; 13: 613.

13. Zhang H, Liu S, Chen Z, Zu B, Zhao Y. Effects of variations in meteorological factors on daily hospital visits for asthma: A time-series study. Environ Res. 2020 Mar;182: 109115.

14. Canova C, Dunster C, Kelly FJ, Minelli C, Shah PL, Caneja C, et al. PM 10 -induced Hospital Admissions for Asthma and Chronic Obstructive Pulmonary Disease: The Modifying Effect of Individual Characteristics. Epidemiology. 2012;23:607-15.

15. Yalnız E, Uslu Ö, Bolat E, Altın S, Polat G. Does the Hospital Admission of Patients with Respiratory Disease Increase in Izmir When the PM_{10} level is High? Turk Thorac J 2020; 21:32-8.

Figure 1. Probability of an asthma exacerbation in confirmed diagnosed asthma patients who visited the ED considering different exposure times and PM10 levels.