Impact of Short-Term Exposure to Below Recommended PM$_{10}$ 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 1$^{st}$ to December 31$^{st}$, 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 28$^{th}$, 2013 to December 31$^{st}$, 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 bootstrap 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/m$^3$ 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/m$^3$ 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 PM$_{10}$ 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.

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Supplementary References


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