The effect of sand storms on acute asthma in Riyadh, Saudi Arabia

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Submission: 19-03-2014
Accepted: 16-06-2014

Abstract:

OBJECTIVE: Major sand storms are frequent in the Middle East. This study aims to investigate the role of air particulate matter (PM) level in acute asthma in children in Riyadh, Saudi Arabia.

METHODS: An aerosol spectrometer was used to evaluate PM < 10µm in diameter (PM_{10}) and PM < 2.5 µm in diameter ($PM_{2.5}$) concentrations in the air every 30 minutes throughout February and March 2012 in Riyadh. Data on children 2-12 years of age presenting to the emergency department of a major children's hospital with acute asthma during the same period were collected including their acute asthma severity score.

RESULTS: The median with interquartile range (IQR) levels of PM_{10} and $PM_{2.5}$ were 454 µg/m^3 (309,864) and 108 µg/m^3 (72,192) respectively. There was no correlation between the average daily PM_{10} levels and the average number of children presenting with acute asthma per day (r = –0.14, *P* = 0.45), their daily asthma score (r = 0.014, *P* = 0.94), or admission rate (r= –0.08, *P* = 0.65). This was also true for average daily $PM_{2.5}$ levels. In addition, there was no difference in these variables between days with PM_{10} >1000 µg/m^3, representing major sand storms, plus the following 5 days and other days with PM_{10} < 1000 µg/m^3.

CONCLUSION: Sand storms, even major ones, had no significant impact on acute asthma exacerbations in children in Riyadh, Saudi Arabia. The very high levels of PM, however, deserve further studying especially of their long-term effects.

Key words:

Status asthmaticus, sand storms, environmental health, air particulate matter, Saudi Arabia

Asthma is a chronic inflammatory disease of the lung bronchial airways characterized by airway edema, disrupted epithelium, bronchial muscle hyper-reactivity, and excessive mucus secretion. It is one of the most common chronic diseases in all populations.[1] Acute asthma exacerbations are one of the most common causes of emergency room visits especially in children.[2] These exacerbations can be triggered by several factors including upper respiratory tract infections, allergen exposure, exercise, and exposure to irritants such as smoke, detergents, and dust or sand.[3] Sand storms are experienced in many areas around the world, mainly in desert areas, but also in non-desert areas where they may arrive from very distant places thousands of kilometres away.[4] The content of these storms is very complex and is composed mainly of silica, but also includes various metals such as calcium, iron, manganese, and aluminium[5,6] as well as other non-ionic components such as NO_2 and SO_2, all are clinically relevant.[6,7]

Dust particulate matter (PM) <10 µm in diameter (PM_{10}) can reach the main bronchial airways and may induce respiratory symptoms like cough.[8,9] However, PM <2.5 µm in diameter ($PM_{2.5}$), also called fine particles, are able to reach the smaller airways and hence was found to be associated with more significant worsening of asthma symptoms and respiratory function.[10] In addition, $PM_{2.5}$ was shown to be associated with upregulation of TH2 inflammatory cytokines and eosinophilia in asthmatic children.[11]

Major Sand storms are frequent in the Middle East[12,13] and the Arabian Peninsula is the second main source of sand storms in the world after the Saharan desert in Africa.[14] Recently, the average monthly deposition of dust in Riyadh City, Saudi Arabia was estimated to be 42.09 tons/km^2.[5] It is a common public and media perception in many Middle Eastern countries that asthmatic patients are at very high risk of developing acute exacerbations during these sand storms. This may lead to increased rate of absence from work or school. However, literature addressing this problem in the Middle East is very scarce and as far as we know this risk has not been evaluated scientifically in the local environment. In this study we aim to investigate the correlation between the level of PM concentration in the air and the rate of emergency department (ED) visits or hospital admissions of children with acute asthma in Riyadh city.

Access this article online
Quick Response Code:
Website: www.thoracicmedicine.org
DOI: 10.4103/1817-1737.146857

Methods

Assessment of dust in the air

The concentrations of PM_{10} and $PM_{2.5}$ were measured using a Grimm Environmental Dust Monitor (EDM) 365 aerosol spectrometer (Grimm Aerosol Technik GmbH, Ainring, Germany). The device [Figure 1a, b], an optical particle counter (OPC), is an instrument for real-time measurement of particulate matter using laser-light-scattering technology. Air containing multiple particle sizes passes through a flat laser beam produced by a precisely focused laser and several collimator lenses. The scattered light is then detected by a 15-channel pulse-height analyzer for size classification. The data is subsequently presented as PM_{10} and $PM_{2.5}$. This instrument can run for long periods without specific supervision. The readings were taken every 30 minutes during February and March 2012, a period of frequent sand storms. The validity of the measurements performed by the instrument has already been established.[15] The aerosol spectrometer was installed at King Khalid International Airport in Riyadh, which is located just north to the city away from heavy traffic and any industrial establishment or factories.

Patient population

Children 2-12 years of age who presented to the ED with acute asthma during February and March 2012 were included. Information on those patients was collected as part of a clinical trial.[16] Children were considered asthmatic if they were prediagnosed by a physician or had a previous episode of shortness of breath that responded to a β2-agonist. A well-validated acute asthma clinical severity scoring system, with a score range from 5-15, where 15 is the most severe, was used to classify the severity of the attack.[17] The asthma score was composed of five different variables: respiratory rate, oxygen saturation, auscultation findings, retractions, and dyspnea. The hospital's institutional review board (IRB) approved the study.

Statistical analysis

Arithmetic mean of patient's asthma score and frequencies of screening and admission were computed for each day of the month to create a summarized daily record of the above mentioned variables and was merged to the daily records of PM_{10} and $PM_{2.5}$ data in February and March 2012. Daily record was considered as a unit of analysis. Normality of the variables was assessed using Shapiro-Wilk test. Median and interquartile range (IQR) of the variables was computed for each group of days. Spearman correlation coefficient was used to assess association of the average daily PM_{10}, $PM_{2.5}$, and (PM_{10}-$PM_{2.5}$) level with the average daily asthma score, number of patients screened, or admitted. Based on published literature[18,19], two groups of days were defined; days with average $PM_{10} > 1000$ μg/m^3 plus the following 5 days (representing major sand storms) and days with average $PM_{10} < 1000$ μg/m^3. Average daily asthma score as well as the number of patients screened or admitted were compared between the two groups using non-parametric (Mann-Whitney U) test. Statistical software Stata version 12 (StataCorp, Texas) was used for all statistical analyses.

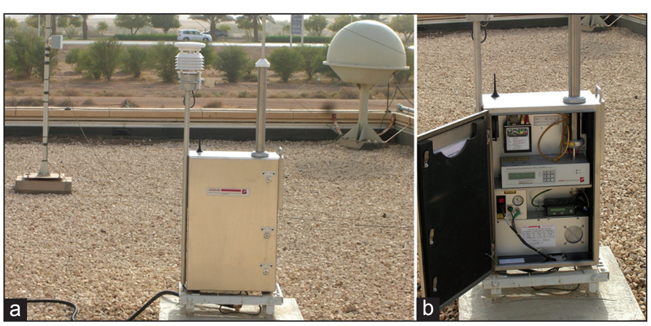

Figure 1: a. General outside view of the GRIMM EDM 365 Environmental dust monitor fixed near King Khalid International Airport in Riyadh. b. Open view of the GRIMM EDM 365 Environmental dust monitor.

Results

Recordings of dust density

The level of dust density was recorded every 30 minutes throughout the study period. The maximum level of PM_{10} recorded was 7873 μg/m^3 on February 2nd with an average level on that day of 2215 μg/m^3 and the minimum was 35 μg/m^3 on February 5th with an average level on that day of 132 μg/m^3. The maximum level of $PM_{2.5}$ recorded was 2160 μg/m^3 with an average day level of 554 μg/m^3 and the minimum was 7 μg/m^3 with an average day level of 28 μg/m^3 on the same days as for PM_{10} respectively. Figure 2 shows the average daily recordings of PM_{10} and $PM_{2.5}$ throughout the study period. There was almost perfect correlation between the levels of coarse particulate matter (PM_{10} - $PM_{2.5}$) and the levels of the fine particulate matter ($PM_{2.5}$) on the same time points ($r = 0.98$, $P < 0.0001$). Overall, the median (IQR) levels of PM_{10}, PM_{10} - $PM_{2.5}$, and $PM_{2.5}$ were 454 μg/m^3 (309,864), 352 μg/m^3 (222,634), and 108 μg/m^3 (72,192) respectively. The mean $PM_{2.5}/PM_{10}$ ratio during the entire study period was 0.25.

Relationship between dust density and acute asthma

There was no correlation between the daily PM_{10} level and the number of children presenting with acute asthma ($r = -0.14$, $P = 0.45$) [Figure 3]. There was also no correlation between the daily PM_{10} level and the asthma scores of patients presenting in the same day ($r = 0.014$, $P = 0.94$) [Figure 4]. Moreover, there was no correlation between the PM_{10} level and the number of asthmatic children admitted per day ($r = -0.08$, $P = 0.65$). The same was true for the coarse (PM_{10}-$PM_{2.5}$) and fine ($PM_{2.5}$) particulate matter levels (data are not shown).

When comparing the days with very high dust density ($PM_{10} > 1000$ μg/m^3)[19] plus the following 5 days and the other days with $PM_{10} < 1000$ μg/m^3, there was no difference between the number of acute asthma cases seen per day in the ED, their asthma score, or the number of patients admitted per day between both groups [Table 1].

Discussion

Our findings indicate that there is no effect of sand storms, even heavy ones on the incidence or hospital admissions of acute asthma in children regardless of the severity of the exacerbation. This is contrary to the common public belief locally that sand storms lead to asthma exacerbation. We attempted to measure peak expiratory flow rate (PEFR) in

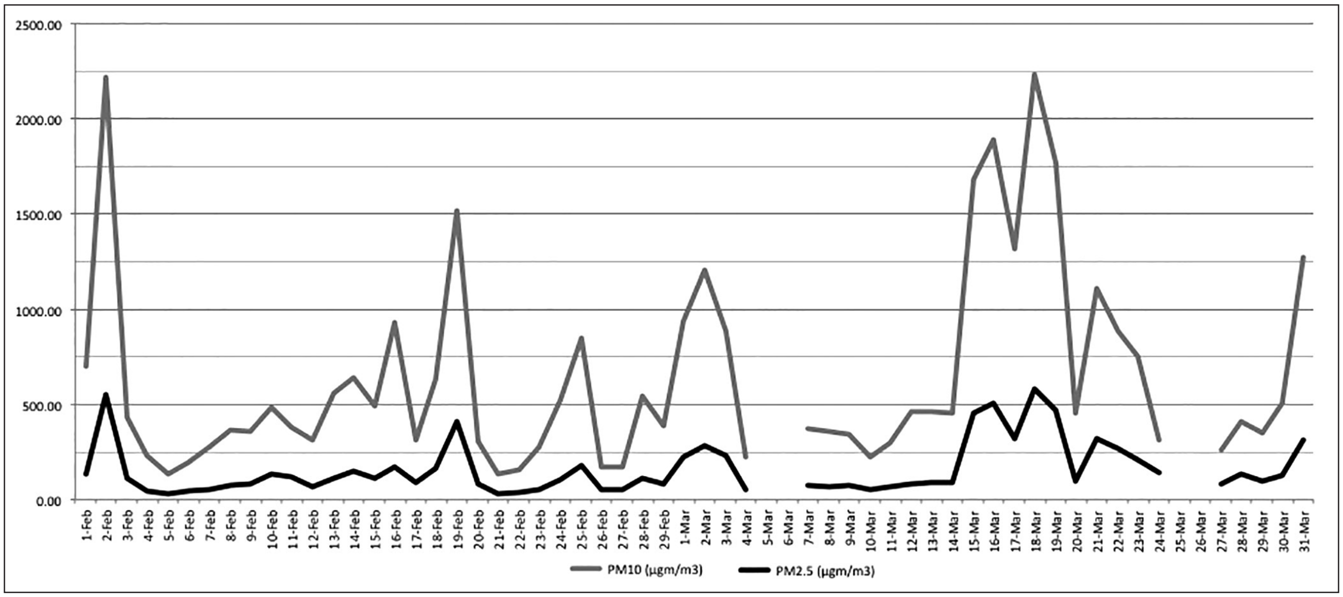

Figure 2: Average daily recordings of PM_{10} and $PM_{2.5}$ during February and March, 2012. The recordings of March 5,6, 25, and 26 were not available.

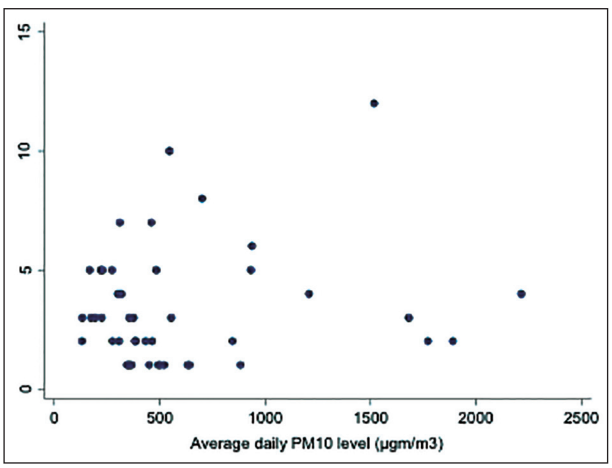

Figure 3: Correlation between average daily PM_{10} level and the average number of children presenting to the emergency department with acute asthma (y-axis).

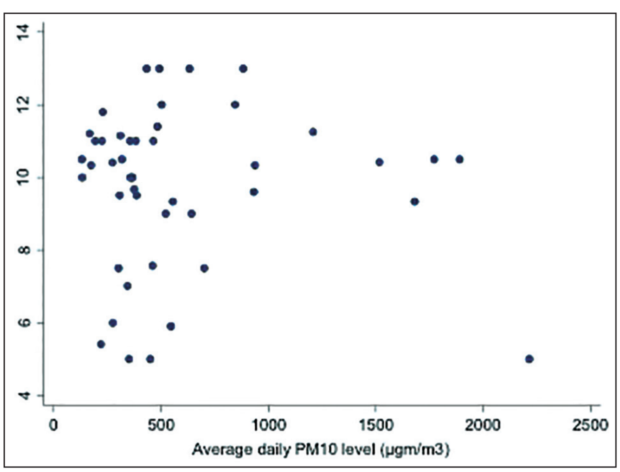

Figure 4: Correlation between average daily PM_{10} level and the average daily asthma score of children presenting to the emergency department with acute asthma (y-axis).

Table 1: Comparison between days with PM_{10} > 1000 µgm/m³ and the following 5 days with other days during the study period in relation to different clinical variables.

	Days with PM_{10} > 1000 µgm/m³ + 5 days (*n* = 27)	Days with PM_{10} < 1000 µgm/m³ *(*n* = 29)	*P*-value
Median (IQR) asthma score	10.5 (9.5,11)	10 (7.5,11.1)	0.471
Median (IQR) number of asthma patients screened per day	3 (2,4)	3 (1,5)	0.896
Median (IQR) number of asthma patients admitted per day	0 (0,1)	1 (0,1)	0.155

*Do not include the 5 days that follow the days with PM_{10} > 1000 µgm/m³, IQR = Interquartile range

our patients as another marker of respiratory function, but the vast majority failed to do the test appropriately. The very wide variation between the sequential daily PM concentration measurements that is sometimes observed within only few days probably reflects the pattern of sand storms that may come suddenly and fade quickly. In addition, the average PM_{10} and $PM_{2.5}$ levels recorded in this study are higher than the average levels reported from previous studies in the Middle East[12,13], which are already much higher than the average levels in many other regions in the world.

The results we had are consistent with those of several other studies on the effects of dust storms or air pollutant levels on asthma exacerbations. These studies showed no increase in ED visits[20,7], hospital admissions[21], or both[4,19] of patients with acute asthma neither in the day of the dust storm event and up to 7 days post-event nor with the PM concentration in the air. These reports came from different parts of the world including South-East Asia[20,22], the Caribbean[4], Europe[7], and the USA[19]. It is important to know that most of these studies reported daily PM_{10} levels that never exceeded 500 µg/m³/day, which is much below the highest daily levels we are reporting here. Hefflin et al., however, reported PM_{10} levels of around 1500 μg/m^3 in Washington State, USA in few occasions[19]. On the other hand, some other studies showed increased hospitalization due to asthma exacerbation after exposure to sand storms.[18,23]

Although the very high PM levels reported in our study were not associated with asthma exacerbations, their long-term effects should be thoroughly investigated. Many large-scale studies have demonstrated that PM air pollution above standard levels is associated with increased morbidity and mortality from respiratory and cardiovascular diseases in the long-term and more markedly with fine PM as compared to coarse PM.[18,24,25] More relevant to patients with asthma, the levels of PM, especially fine PM correlated more with bronchial inflammatory markers upregulation including exhaled NO and different inflammatory cytokines as well as aggravation of mild respiratory tract symptoms like cough or causing mild drop in PEFR.[9-11,20,26] The US National Ambient Air Quality Standards (NAAQS) maximum accepted level for 24-hour $PM_{2.5}$ is 35 μg/m^3 and for 24-hour PM_{10} is 150 μg/m^3.[27] The annual maximum accepted levels for $PM_{2.5}$ and PM_{10} were 12 μg/m^3 and 50 μg/m^3 respectively. These levels are much lower than our median values of $PM_{2.5}$ and PM_{10}.

Our study may be limited by the lack of information on specific metal particles (like iron, silica, cadmium, or aluminium) concentration in the air or ionic particles (like SO_2 or NO_2) that were shown to have significant effect on pulmonary function in some studies [6,10,7,28]. In addition, this is a single center study, which may limit data generalizability. With the low effect size of stand storms on acute asthma, as implied by the very low correlation coefficient, it seems unlikely to observe positive correlation with higher patient number. Utilizing multiple clinical centers as well as using multiple sites for recording PM density for longer periods of time should, nevertheless, provide more information and may still detect more subtle effects of sand storms on acute asthma.

In conclusion, our findings suggest that there is no need for an alarm to be raised in emergency rooms in the event of a sand storm because of fear of overcrowding by patients with asthma exacerbations. On the other hand, the very high levels of fine and coarse particulate matter call for further studies especially on their long-term effects.

Acknowledgement

We would like to thank Prof. Muslim Alsaadi for his advice and review of the manuscript.

Funding

This study was supported by a grant from the Strategic Technologies Program of the National Plan for Science, Technology, and Innovation (NPSTI) in the Kingdom of Saudi Arabia. Grant number is 08-MED520-02.

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How to cite this article: Alangari AA, Riaz M, Mahjoub MO, Malhis N, Al-Tamimi S, Al-Modaihsh A. The effect of sand storms on acute asthma in Riyadh, Saudi Arabia. Ann Thorac Med 2015;10:29-33.

Source of Support: Nil, **Conflict of Interest:** None declared.