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ORIGINAL ARTICLE

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African dust clouds are associated with increased paediatric asthma accident and emergency admissions on the Caribbean island of Trinidad

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Abstract A retrospective ecological study of paediatric asthma patients who attended the Accident and Emergency (A&E) department of the Paediatric Priority Care Facility at the Eric Williams Medical Sciences Complex in relation to Saharan dust visibility and other climatic variables for the period 23 May 2001 to 13 May 2002 was undertaken to determine if there is an association between paediatric A&E asthma visits and Saharan dust cloud cover. A Poisson regression model was used to determine the statistical relationship between acute paediatric asthma A&E visits and Saharan dust cover with and without other variables such as climatic parameters and month. During the study period, there were 2,655 A&E visits for acute asthma. There was an association between increased paediatric asthma admissions and increased Saharan dust cover. The best fitting model estimated that in one month, such as June, a deterioration of visibility due to increased Saharan dust cover from no dust (visibility =16 km) to very dusty (visibility= 7 km) would increase a daily admission rate of 7.8 patients to 9.25 when climate variables such as barometric pressure and humidity were kept constant.

Keywords Saharan dust · Paediatric · Asthma · Accident and emergency · Caribbean

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Introduction

The Caribbean, like other territories worldwide, has seen an increase in the prevalence of allergic diseases over the past 30 years (Lenfant 1993). The paediatric population has been particularly affected. For example, the prevalence of asthma among Barbadian school-aged children has reportedly increased from 1% in 1970 to 15% in 1996 (Pearson 1973; Howitt et al. 1997). In Trinidad, a survey of secondary school-aged children showed that 25% of children had suffered with asthma symptoms in the year before the study (Tam Tam et al. 1998). The high prevalence of asthma in Caribbean children and the alarming increase noted in the last 30 years may be due to environmental changes in the region. One environmental factor that has shown striking change between 1970 and the present is the increase in the concentration of Saharan dust in the Caribbean atmosphere (McCarthy 2001).

African dust clouds are borne regularly across the Atlantic Ocean by the North Atlantic Trade Winds to the Caribbean, southern states of the United States and the South American mainland. These clouds bring millions of tons of dust to these regions annually. In 1970, severe drought in the Sahel led to a dramatic increase in the quantity of Saharan dust transported to the Caribbean. Twenty million tons of dust particles are estimated to arrive in the Caribbean annually (Schlatter 1995). Most dust particles are less than 1 μm in diameter and could potentially reach the smallest airways. The main constituents are clay, minerals (especially iron) and quartz but Saharan dust clouds also contain microorganisms, pollen and various other plant-derived materials (Prospero 1999). These latter constituents are potential sources of infectious and allergenic agents, which could theoretically contribute to human respiratory disease.

In Trinidad, while there is a popular belief that Sahara dust worsens rhinitis and asthma there has been no comprehensive study to determine if there is a relationship between Saharan dust cover and such allergic diseases. A report from Barbados which investigated acute asthma admissions in relation to African dust cloud cover over that

island found no discernible relationship and the authors suggested that the microbial content of the dust may be of greater importance to the development of acute asthma than the concentration of dust particles in the atmosphere (Blades et al. 1998). It is noteworthy however that these researchers, despite postulating a microbial cause of acute asthma following dust cover, did not explore the possibility of a lag or latency interval between dust cover and acute asthma visits in their analysis.

Descriptive epidemiological studies from several islands in the Caribbean all show that allergic diseases are more common among children and adolescents. In Trinidad, a demographic description of patients attending A&E departments across the island revealed that 52% of all cases were paediatric and adolescent patients with 33.4% being less than 10 years of age (Monteil et al. 2000). In exploring any potential association between Saharan dust and acute asthma A&E admissions, paediatric cases would constitute the majority of such admissions. Furthermore, children have smaller airways making them more susceptible to the clinical consequences of airway inflammation resulting from allergen, microbial or irritant exposure and may provide a more sensitive barometer of the potential effects of Saharan dust on human disease. We therefore chose to investigate potential associations between Saharan dust and paediatric acute asthma visits.

The object of the study was to determine if there was any association between the presence of Saharan dust clouds in the atmosphere over Trinidad and paediatric acute asthma visits. Since dust clouds may be affected by other prevailing climatic conditions, we also explored possible associations between Saharan dust cover and other climatic variables.

Methods

Study design

A retrospective ecological study was used to investigate the association between Saharan dust days and paediatric A&E visits to the Eric Williams Medical Sciences Complex, Trinidad. Paediatric patients' A&E records were reviewed and Saharan dust cover and climatic variables data were collected for the period from 23 May 2001 up to and including 13 May 2002.

Patient selection

The study population consisted of patients aged 15 years and under who attended the Paediatric Priority Care Facility (PCF) of the Wendy Fitzwilliam Children's Hospital, Eric Williams Medical Sciences Complex (EWMSC) during the study period. For inclusion in the study, patients had to have been diagnosed by the A&E physicians as suffering from one of the following: mild/moderate asthmatic attack, acute asthmatic attack or unresolved asthmatic attack, and to have received bronchodilator nebulization at the PCF. The number of children treated for asthma per day was recorded from the A&E attendance records. Demographic and clinical data for patients meeting the inclusion criteria were recorded from the patients' register. Each patient's age, gender, address and additional clinical conditions other than asthma, such as respiratory infection, were recorded.

Saharan dust and climate data

Data on Saharan dust visibility (km) and climate variables including total rainfall (mm), relative humidity (%), average barometric pressure (kPa), maximum temperature (°C), minimum temperature (°C), temperature difference (°C), average wind speed (km/h) and thunderstorm data were obtained from the Meteorological (MET) Office for the period 23 May 2001 up to and including 13 May 2002. This period covered one rainy season and one dry season. The MET Office is located 16 km away from the EWMSC. The MET Office uses a standard scale of visibility to measure Saharan dust levels. The greater the volume of dust, the shorter the visibility, recorded in kilometres of visibility. As dust levels approach a minimum detectable level the visibility increases above 15 km. The MET Office defines a Saharan dust day as a day in which there is a reduction in visibility equal to or less than 15 km. Sahara dust haze has a reddish-brown colour that allows it to be distinguished from other causes of haze.

Ethical approval

The Ethics Committee of the Faculty of Medical Sciences, University of the West Indies approved this study. The Medical Chief of Staff and the Director of Paediatrics at the EWMSC kindly gave permission for the collection of data from A&E records.

Statistical analysis

The data, number of paediatric visits over 356 days, climate variables and Saharan dust visibility were initially explored using a variety of graphical devices. For example, a time series plot was constructed to observe trends in the number of daily visits during the study period. Correlation coefficients between weather variables was examined and these variables were found not to be uncorrelated (see Appendix 1). As the data set spans 1 year only, a rigorous examination of seasonality was not possible but some indication of seasonal effects was obtained by using month as a predictor variable. All climatic variables, month and visibility associated with Sahara dust cover were included in the model. The variables which appeared to have the greatest effect on asthma admissions included month, visibility, pressure, temperature and humidity and these were analyzed further. Rainfall and humidity had the largest correlation (correlation coefficient 0.53) and so we chose to consider humidity only since the two variables would yield overlapping information in any model. Lagged effects up to 7 days were assessed.

Development of a statistical model

The main predictor variables used in modeling were month, barometric pressure, relative humidity, temperature and dust visibility. These variables were continuous but dust visibility was recorded as an integer. The Poisson regression routines of S-plus v6.2 statistical package (Mathsoft, Cambridge, Mass., USA) were used to model the log of the mean of daily asthma visits as a function of the following variables: month, visibility, atmospheric pressure, humidity and temperature. The variables were introduced in the order given and up to two-way interactions were considered.

Results

Demographic features of patients attending for acute asthma care

At the study centre, the 2,655 asthma visits recorded during the study period consisted of patients from towns in all eight counties on the island. However, most visits were from areas along the East-West Corridor (a major urban thoroughfare extending westerly from Arima, the third largest town in the country towards the capital city of Port-of-Spain). Male visits were significantly higher than the females within all age groups ($P<0.0001$) and the sex ratio was 1.58 M: 1F (refer to Fig. 1).

Distribution of climatic variables

There was significant variation in the daily visits by month during the study period with the highest mean number of visits occurring in November (Table 1).

The time series plots of daily asthma visits and Saharan dust cover and weather variables are illustrated in Fig. 2a and b. In Fig. 2a Saharan dust cover (here shown as 1/visibility $\times 100$) was noted on 96 days (27%) of the study period and occurred in most months except November. There was relatively little dust detected from mid-October to mid-January while the heaviest dust cover days (dust visibility ≤ 7 km) occurred several times during the dry season and in the first half of the rainy season; from mid-January to mid-February, end of March to early April, mid-June to mid-July and end of August to mid-September.

As seen in Fig. 2b, the barometric pressure persisted at a medium to high range (between 1,012.1 and 1,017 kPa) for the first 90 days of the study. It fell and achieved a nadir of 1,007 kPa at day 208. The pressure rose rapidly from day 208 to a medium to high range on day 230 and continued there until the end of the study period. In contrast, daily humidity fluctuated between 69 and 95% throughout the study period.

Poisson regression model

Summary statistics for the number of daily visits and predictor variables (Sahara dust visibility, relative humidity, temperature and barometric pressure) used in modeling are presented in Table 2. The variable "month" had the largest main effect, as determined by a decrease in deviance as each parameter was added to the model (Table 3). Relative humidity and visibility also had main effects. All two-way interactions involving month, including month and visibility, were significant ($P<0.05$). From our model, it was estimated that in one month, such as June, a deterioration of visibility due to increased Sahara dust cover from no dust (visibility = 16 km) to very dusty (visibility = 7 km) would increase a daily admission rate of 7.8 to 9.25 when climate variables such as barometric pressure and humidity and temperature were kept constant. Lagged effects of two or more days had no impact on the number of daily visits.

The study contained several "extreme" observations, most of which are identified as outliers no matter what model was used. The majority of these events occurred when days were dust-free and weather conditions were not extraordinary. They may represent asthma outbreaks due to causes other than those considered in this study.

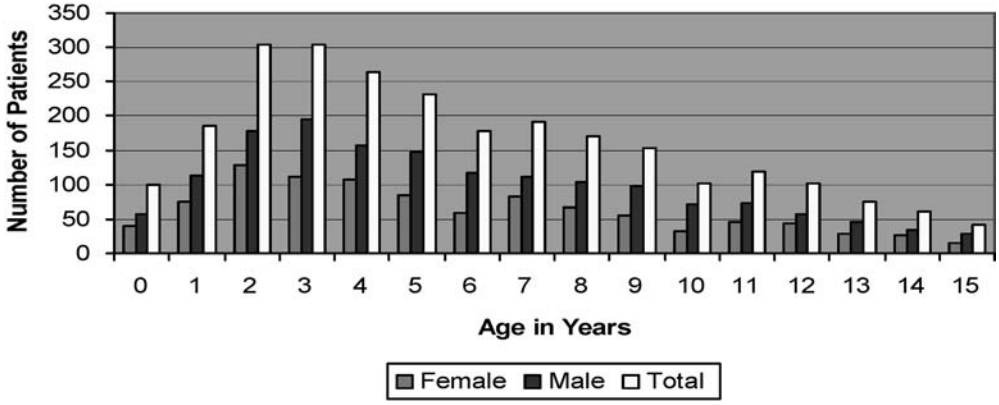

Fig. 1 Distribution of female, male and total paediatric asthma visits categorized by age

Table 1 Mean number of daily asthma visits by month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
7.0	5.42	6.48	8.30	8.95	7.07	6.77	4.52	7.83	8.35	13.0	6.35

Table 2 Summary statistics of daily visits and predictor variables used in modeling

No. of visits per day over the 356 days of observations		Dust visibility (km)	Relative humidity (%)	Mid temperature (°C)	Barometric pressure (kPa)
Minimum	0.00	6.0	69.0	24.75	1,008.1
Maximum	28.0	16.0	95.33	29.75	1,016.6
Mean	7.47	14.04	82.74	27.67	1,013.35
Median	7.0	16.0	82.33	27.78	1,013.6
Variance	18.19	12.21	26.73	0.77	2.42
Standard deviation	4.27	3.49	5.17	0.88	1.56

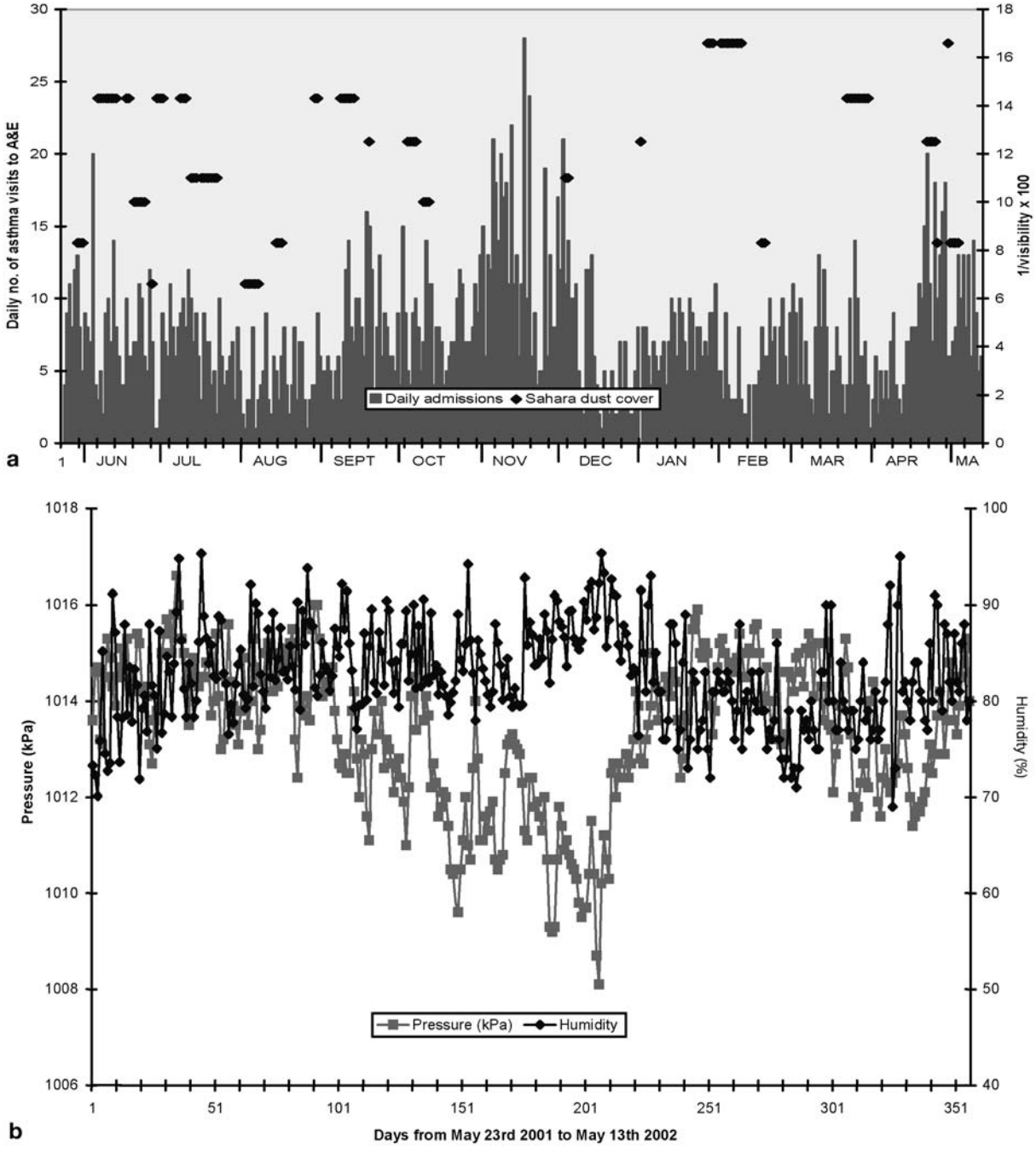

Fig. 2 **a** Daily asthma visits to the paediatric A&E department for the period 23 May 2001 to 13 May 2002. **b** Daily meteorological factors (barometric pressure and humidity) for the period 23 May 2001 to 13 May 2002

Table 3 Changes in deviance with addition of dust and climate variable to the statistical model

Variable added	Degrees of freedom	Deviance
Null	354	820
Month	343	632
Month, visibility	332	598
Month, visibility, pressure	319	552
Month, visibility, pressure, temperature, humidity	290	495

Discussion

In this study there were more male than female paediatric asthma visits. This is consistent with previously published global and regional reports, which show that asthma in the paediatric group is more common in males than females.

This is the first report as far as we are aware of an association between Saharan dust cover and human respiratory disease in the Americas; specifically, exacerbation of paediatric asthma. Our results argue in favor of an irritant and/or allergic aetiology for the noted increase in acute asthma following Saharan dust cover. Infectious agents, as triggers of airway inflammation, would be expected to have incubation periods of several days before the onset of symptoms. Potential allergens and irritants in Saharan dust include plant-derived constituents such as pollens and the high iron content in the form of surface-complexed iron. Aerosols rich in transition metals are reportedly efficient in producing pulmonary inflammation (Prospero 1999).

Since the early 1990's when Eugene Shinn and colleagues suggested that fungi in Saharan dust was a possible cause for the death of coral in North Caribbean reefs (Shinn et al. 2000), there has been considerable interest in Saharan dust and human disease. Members of Dr. Shinn's group investigated the sale of antihistamines in the US Virgin Islands during periods of Saharan dust cover and found no correlation (personal communication to Dr M.A. Monteil). In Barbados, Blades et al. found no association between A&E asthma visits and Saharan dust cover (Blades et al. 1998). It is likely that the significant association reported in our study can be attributed to the deliberate targeting of a paediatric population versus an adult or mixed (children and adults) population. Children have smaller airways, which may render them more susceptible to the allergenic and/or irritant components of Saharan dust.

Many of the children attending the EWMSC during the study period were from towns along the East-West Corridor, which contains some of the heaviest traffic in Trinidad. Moreover, many homes are situated very close to these busy roads. In their study of suspended particulate matter concentrations along the East-West Corridor Rajkumar and Chang showed that temporal variation in particulate matter (PM) with an aerodynamic diameter of $\leq$10 μm (that is, PM_{10}) "was principally associated with the presence of Saharan Dust" (Rajkumar and Chang 2000). These authors further demonstrated that the three highest 24 h PM_{10} concentrations observed at three study points were found on days of Saharan dust cover. These values range from 135.59 to 149.98 $\mu g.m^{-3}$ compared with 30–40 $\mu g.m^{-3}$ during non-Saharan dust periods. It is possible children living or attending schools in these areas inhale increased amounts of particulates consisting of Saharan dust and exhaust pollutants with resultant exacerbation of asthma.

The most significant variable was "month" which was used as a measure of seasonality. Previous reports from Trinidad and other islands have shown that asthma admissions are more common in the latter half of the rainy season, from September to December (Ivey et al. 2001, 2003; Depradine et al. 1995). Thus, the finding that asthma admissions were highest in November is consistent with previous reports. However, there are other periods of increased asthma admissions most notably in May to June and February to March (Depradine et al. 1995). It is likely that Saharan dust cover does not have a role in the large increase in asthma visits noted in the latter part of the year when there is almost no Saharan dust cover the island of Trinidad. However, Saharan dust cover could be a major contributor to the smaller peaks of asthma admissions noted in the dry season and in the transition period (May to June) between the dry and rainy seasons.

Climactic variables such as barometric pressure, temperature and relative humidity have been shown to be associated with emergency room asthma visits in Trinidad. Barometric pressure and temperature difference were predictors of paediatric emergency room visits (Ivey et al. 2003) while relative humidity and minimum temperature were linearly related to adult asthma visits. Overall visits tended to be increased when there was high relative humidity and low barometric pressure. Climatic factors only accounted for 14% of variance suggesting that other factors were important in increasing the number of acute asthma admissions.

There were several limitations in this study. Firstly, the study period of 2 years initially chosen for this study was not achieved because of poor record keeping in the paediatric PCF during 2000 and the first few months of 2001. A single year of data prevents us from commenting on seasonal trends. Secondly, climatic variables and dust cover data were collected from the island's sole meteorological station which is situated 16 km from the study hospital and much of the East-West Corridor and thus we are unable to comment about the microclimatic environment around the EWMSC and the East-West Corridor. Finally, our data assumes that all people in Trinidad are exposed to the same climatic variables at the same time, which may not be true (the ecological fallacy).

The aforementioned limitations and the need for a larger dataset to allow improved statistical analysis of the interactions of dust and climatic variables suggests that a prospective study of asthma admissions in relation to dust cover

should be conducted for several years. Our proposed study would also incorporate a comparison of general air quality on "dust" and "dust-free" days. Examination of the contents of the Saharan dust would also be beneficial, as this would allow the identification of specific constituents that may be potential triggers of severe asthma. It would also be useful to quantify dust cover rather than rely on long range visibility as a measure of dust cover density.

Asthma is a major community health problem in Trinidad. Knowledge of specific local environmental triggers of acute asthma will provide local healthcare practitioners and their asthmatic patients with relevant information for the development of specific preventative strategies. These in turn will lead to less asthma morbidity and mortality in Trinidad and Tobago.

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Appendix 1: Correlations between climactic variables used in modeling

Taba

Rainfall		Humidity	Pressure	Mid-temperature
Rainfall	1.000	0.531	−0.097	−0.178
Humidity	0.531	1.000	−0.311	−0.153
Pressure	−0.098	−0.311	1.000	−0.136
Mid-temperature	−0.178	−0.153	−0.136	1.000

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