Thermoregulation and Periodically Forced SEIR model: Understanding asthma seasonality in South Florida
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Abstract

The impact of changing weather and air quality conditions on cardio-respiratory diseases is very important. Epidemiological as well as biomeology studies have documented the existence of exacerbating factors for asthma, different from other common ailments. Economic conditions, educational backgrounds, stress, diets, along with weather and air quality conditions appear to cooperate and complement the allergen hypothesis. Motivated by these facts and aimed at understanding the inner working of asthma, time series of Emergency Department (ED) visits due to asthma in Miami Dade and Broward Counties were provided by the Florida Asthma Coalition for six years (2005-2011) with daily temporal resolution. They show a peak of attendance between the months of November and January and a minimum between the months of April and June every year.

The time series of weather parameters (Temperature, Humidity, Wind Speed and direction, Pressure, Diurnal range of both temperature and humidity, and Extremes of both temperature and humidity) were obtained from the Weatherbug sensor in South Florida. Surface ozone, and particulate matter were obtained from EPA registered stations. Time series and correlation analyses between weather variables and the number of cases resulted in weak to moderate associations mainly with the minimum and mean temperature, the mean humidity, and some derived thermal indexes. Lagging effects were analyzed up to seven days previously to ED visit.

1. Motivations

• How far weather and air-quality conditions do affect the triggering of Asthma in South Florida (Miami Dade County)?
• What variables might serve as best predictors for Asthma outbreaks?

2. Miami Dade Weather and Climatology

Miami Dade Climatology

Fig. 3: Geographical locations of automated weather stations from Weatherbug measuring stations in Miami Dade County.

Fig. 4: Time series of: (Upper left panel) Ambient maximum and minimum temperature, (Bottom left panel) Diurnal temperature range, (Upper central panel) Relative humidity maximum and minimum, (Bottom central panel) Humidity range, (Upper right panel) Mean values of the barometric pressure, and (Bottom right panel) Maximum wind speed.

4. Linear Regression and Lagging Analysis

Why negative thermal loading is so relevant?
• Keystone in the etiology of acute respiratory diseases
• Respiratory heat losses above the norm (15 W – effective heat loss) lead to high frequency of respiratory diseases in children.
• High heat losses from respiratory organs make it easier for pathogens to penetrate the protective barriers of lungs and may be the reason for increased morbidity.

Q = C x E
C = 1.17 x 10^6 (T – Tc) x A
E = 2.3 x 10^3 M (Tc – T)
M = Metabolic heat rate (W/m^2)
A = Surface body area (m^2)
T = Body core temperature (°C)
Tc = Ambient air temperature (°C)
e = vapor pressure of core air (mm Hg)
M = 20 W/m^2 person standing relaxed
a = 44 mm Hg
Tc = 37°C

Fig. 5: (Left panel) Elements from the weather with direct impact on respiratory health. (Right panel) Net Effective Temperature. It incorporates the joint effect of the ambient temperature, humidity level and wind speed.

3. Wind patterns and Air Quality

Revolving Winds Over The Years

Fig. 7: Time series of both ground Ozone (O) from EPA in Miami Dade County.

5. Seasonally Forced SEIR models

Fig. 11: Multiple agents might lead to asthma as sooner weather conditions may promote their proliferation and incidence. $[\beta(t) = \beta_0 + \beta_1 \sin(2\pi t/T)]$
Seasonally forced infection rate

Fig. 12: Schematic representation of the SEIRS model (left panels), where S = susceptible, E = exposed, I = infected, R = recovered individuals. $[\beta(t)]$ is the seasonally forced infection rate used to model the seasonal incidence of epidemics affecting asthmatic patients, or is the rate exposed individuals are becoming infected, while $y(t)$ is the recovery rate. In the right panel, the SEIRS model is represented in the event of two viral infections happening simultaneously during the season and both leading to asthma and recovery patients not showing asthma.

Table 1: Average daily number of ED visits due to asthma in Miami Dade.

Table 2: Projected State of Florida Building Resilience Against Climate Effects

Conclusions

• Asthma is a complex disease demanding a system-based approach.
• Weather influence happens directly as well as indirectly.
• The link of strong correlation between weather parameters and the number of visits to the ED may be associated with the robustness of the respiratory system to environmental changes.
• Weather seems to affect more the exposure to epedemics than the thermal regulation.

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