Modeling the association between the seasonal asthma prevalence and upper respiratory infections.

Aidin Alejo [1,2], David Quesada [2,*]

[1] Miami Dade College, Wolfson Campus, Miami FL , USA; E-Mail: aidin.alejo001@mymdc.net

[2] School of Science, Technology, and Engineering Management, St. Thomas University, Miami Gardens, FL 33054, USA; E-Mail: dquesada@stu.edu;

* Author to whom correspondence should be addressed; E-Mail: dquesada@stu.edu;
Tel.: +1-305-474-6910; Fax: +1-305-628-6706.

Received: / Accepted: / Published:

Abstract: Asthma affects a considerable amount of people worldwide from pediatric to elderly age group. This communication addresses the association between the seasonality of asthma in South and Central Florida with the occurrence of Upper Respiratory Track Infections (URTIs). Motivated by a statistical analysis of the Emergency Department visits due to both, asthma as the primary diagnosis and URTIs excluding asthma for eight consecutive years, a compartmental model, that extends the SEIR model is analyzed and contrasted with health data. It is hypothesized that asthma seasonality is likely to be associated with the thermal stress generated during the process of respiration in winter months, predisposing the lining of the epithelial cells due to the lack of humidity along the respiratory tract. Such a situation exposes the body to infections and exacerbates the response of the immune system accordingly. At the end, an inflammatory process results and asthma develops.

Keywords: *asthma, upper respiratory tract infections, thermal stress, SEIR dynamical systems, and seasonality.*

Introduction

Asthma is a condition affecting a considerable body of people worldwide and contributes to both, the economic and social burden of many families. In a previous communication by one of the authors [1], a statistical analysis of the number of asthma cases reported at Emergency Departments (ED) versus different weather parameters (temperature, humidity, pressure, ozone levels, and particulate matter) was done and resulting in a low correlation between potential predictors and the number of cases. The analysis was performed using two different schemes and including lagging effects: Generalized Additive Linear and Poisson models. The percentage of variability described by these models did not exceed the 25 %. It motivated the authors to look at an indirect effect of weather conditions on asthma prevalence and exacerbation through thermal stress –induced vulnerability to upper respiratory tract infections.

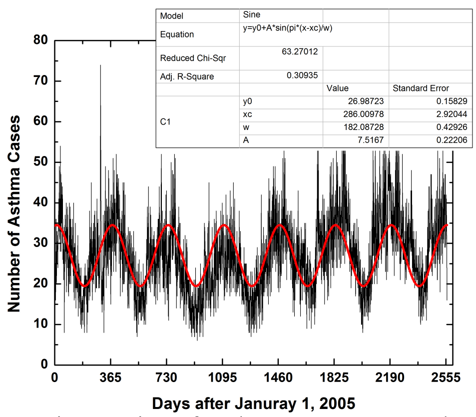
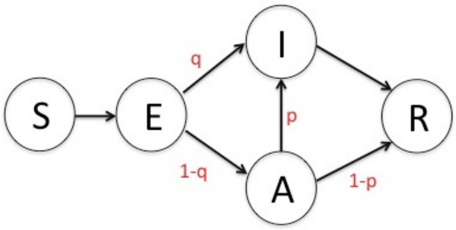


Fig. 1: Time series of asthma cases reported at ED from January 1, 2005 to December 31, 2011. The seasonal component appears in the inset.

Model and Results

The upper respiratory tract plays a very important role in the acclimatization of the human body. Air entering through the nose exchanges humidity and heat with the tract. In winter times, this process leads to sufficient heat losses and therefore, to a considerable thermal stress. As a result, the lining of the upper respiratory tract is affected and immunity depleted. It creates the perfect conditions for infections to penetrate and propagate. Both, asthma and URTIs as a primary diagnosis excluding one another respectively were recorded from counties in the southeast and center of Florida from January 1, 2005 to December 31, 2012. Overall, exacerbations across South Florida show a seasonal pattern, which peaks between January and February. Time series decomposition is shown in Fig. 1, where the sine function accounts for the periodicity of the events. In standardized variable format (z-variable), the effect goes beyond the standard deviation around the mean number of cases per year, thus it is a measurable condition.



$$\frac{dS}{dt} = \mu - \mu\beta(t,3)I(t)S(t)$$
$$\frac{dE}{dt} = \beta(t,3)I(t)S(t) - (\mu+\sigma)E(t)$$
$$\frac{dI}{dt} = p\sigma E(t) + qA(t) - (\mu + \mu_E(t,\gamma))I(t)$$
$$\frac{dA}{dt} = (1-p)\sigma E(t) - (q + \mu + \mu_E(t,\gamma))A(t)$$
$$\frac{dR}{dt} = \mu_E(t,\gamma)I(t) + (1-q)A(t) - \mu R(t)$$

$$\beta(t,\beta_0) = \beta_0\left(1+\sin\left(\frac{2\pi t}{T}\right)\right)$$
$$\mu_E(t,\mu_{E0}) = \mu_{E0}\left(1-\sin\left(\frac{2\pi t}{T}\right)\right)$$

Fig. 2: Scheme of the SEIAR model used in this communication along with the system of ODE resulting from the compartmental representation.

Following the scheme of the SEIR dynamical model, a new one with asymptomatic patients (new compartment, see Fig. 2) is developed in fair agreement with ideas discussed in Ref. [2]. It was labeled as SEIAR model and it was solved with Mathematica. The model was solved for an ensemble of parameters, however after a chi-square test, the values that better fit the recorded number of cases are as follows: $\beta_0 = 3$, $\mu_{E0} = \gamma = 0.24$, $p = 0.7$, $q = 0.3$, $\mu = 0.35$, $\sigma = 0.21$, and $T = 52$.

The solutions for all five variables are depicted in Fig. 3, where the periodicity (seasonality) in the number of infected and asymptomatic individuals is clear. Such a result is also in agreement with results obtained in Refs [3 – 5]. A further analysis of residuals shows that deviations are randomly distributed on both sides of the recorded values with no apparent structure, therefore, it seems to be indicative of epidemic-based triggering channel.

Conclusions

Results of statistical analysis and mathematical modeling support the idea of the weather-induced upper respiratory tract infection for triggering many of the asthma reported cases at ED. A more systematic sensitivity analysis including other triggering options is needed in order to assess how far one option overwhelms the rest. Likewise, it might happen that options that are dominant in some areas might become second hand in others. An ecological epidemiology approach along with mathematical modeling will eventually lead to the understanding of the inner working of asthma episodes.

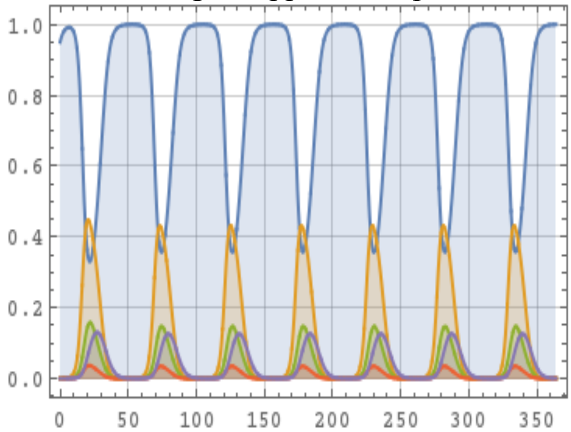


Fig. 3: Solutions of the SEIAR model obtained with Mathematica and showing the seasonality observed in health records.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgments

Authors want to thank St. Thomas University facilities for completing this work during the SRI 2016, as well as the STEM-TRAC grant PO3C110190.

References and Notes

1. Quesada, D.; Davila, Y.; Perez A. South Florida asthma seasonality: evaluating potential predictors for early warning in respiratory health. *Int. J. Biometeorology* **2016**, *to be submitted*.
2. Eccles, R. Title An Explanation for the Seasonality of Acute Upper Respiratory Tract Viral Infections. *Acta Otolaryngol*. **2002**, 122, pp. 183 –191.
3. Keeling M.J.; Rohani P.; Grenfell B.T., Seasonally forced disease dynamics explored as switching between attractors, *Physica D* **2001**; 148, pp. 154–196.
4. Grassly, N.C.; Fraser C., Seasonal infectious disease epidemiology, *Proc. Royal Soc. B* **2006**; 273, pp 2541 – 2550.
5. Junling-Ma, Z.M., Epidemic Threshold Conditions for Seasonally Forced SEIR Models. *Mathematical Biosciences and Engineering* **2006**, 161-172.