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ORIGINAL ARTICLE

# Climate seasonality and lower respiratory tract diseases: a predictive model for pediatric hospitalizations

*Sazonalidade climática e doenças das vias respiratórias inferiores: utilização de modelo preditor de hospitalizações pediátricas*

*Estacionalidad climática y enfermedades de las vías respiratorias bajas: utilización de modelo predictor de hospitalizaciones pediátricas*

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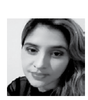



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## ABSTRACT

**Objectives:** to analyze the climate seasonality of respiratory diseases in children aged 0-9 years and present a model to predict hospital admissions for 2021 to 2022. **Methods:** verify, in a temporal manner, the correlation of admissions for pneumonia, bronchitis/bronchiolitis, and asthma with meteorological variables, aiming to demonstrate seasonality with the adjustment of temporal series models. **Results:** there was a seasonal effect in the number of registered cases for all diseases, with the highest incidence of registrations in the months of autumn and winter. **Conclusions:** it was possible to observe a tendency towards a decrease in the registration of pneumonia cases; In cases of admissions due to bronchitis and bronchiolitis, there was a slight tendency towards an increase; and, in occurrence rates of asthma, there was no variation in the number of cases.
**Descriptors:** Climatic Seasonality; Lower Airway Diseases; Hospitalizations; Statistical Bias; Children.

## RESUMO

**Objetivos:** analisar a sazonalidade climática das doenças respiratórias em crianças de 0 a 9 anos e apresentar um modelo para previsão de internações hospitalares para os anos de 2021 a 2022. **Métodos:** propôs-se verificar, de maneira temporal, a correlação de internações para pneumonia, bronquite/bronquiolite e asma com variáveis meteorológicas, visando verificar a sazonalidade com o ajuste de modelos de séries temporais. **Resultados:** percebeu-se, para todas as enfermidades, o efeito sazonal no número de casos registrados, com o maior número de registros nos meses de outono e inverno. **Conclusões:** foi possível constatar uma tendência de diminuição no registro de casos de pneumonia; já para os casos de internações por bronquite e bronquiolite, observou-se uma leve tendência de aumento; e, em relação as taxas de ocorrência de asma, não houve variação.
**Descritores:** Sazonalidade Climática; Doenças das Vias Aéreas Inferiores; Hospitalizações; Viés Estatístico; Crianças.

## RESUMEN

**Objetivos:** analizar la estacionalidad climática de las enfermedades respiratorias en niños de 0 a 9 años y presentar un modelo para previsión de internaciones hospitalarias para los años de 2021 a 2022. **Métodos:** se propuso verificar, de manera temporal, la correlación de internaciones para neumonitis, bronquitis/bronquiolitis y asma con variables meteorológicas, visando verificar la estacionalidad con el ajuste de modelos de series temporales. **Resultados:** se percibió, para todas las enfermedades, el efecto estacional en el número de casos registrados, con el mayor número de registros en los meses de otoño e invierno. **Conclusiones:** fue posible constatar una tendencia de disminución en el registro de casos de neumonitis; ya para los casos de internaciones por bronquitis y bronquiolitis, se observó una leve tendencia de aumento; y, en relación las tasas de ocurrencia de asma, no hubo variación.
**Descriptores:** Estacionalidad Climática; Enfermedades de las Vías Respiratorias Bajas; Hospitalizaciones; Sesgo; Niños.

## INTRODUCTION

Children are a susceptible and sensitive group to weather variations. That can be explained by the immaturity of the immune system and reduced airway caliber, which may be more suppressed in the winter period. Low temperatures promote spasms of the respiratory tract and ischemia due to capillary contraction in children, resulting in weakened ciliary movement and, consequently, difficulty removing viruses and bacteria from the respiratory epithelium. Such situations favor the evolution of severe forms of respiratory diseases, with significant respiratory dysfunction and the consequent need for hospitalization[1-2].

In this context, some diseases are predominant and/or prevalent in certain climate regions; others tend to follow a seasonal pattern (related to weather conditions) in their incidence and have causal factors linked to the environment, with variation in their occurrence. The chronological distributions of specific diseases in terms of maximum and minimum registrations always occur in the same period, whether the year, month, week, or day. In these distributions, the variation is characterized by a particular seasonality related to the property that the phenomenon always repeats itself in the same season. Several studies have investigated the seasonal influence due to potential health risks, especially concerning the respiratory system. Several diseases have seasonal characteristics, such as asthma, pneumonia, bronchitis/bronchiolitis, influenza, chickenpox, meningitis, and pulmonary tuberculosis[3-10].

The autumn and winter seasons are worrying with respiratory diseases, mainly due to the increase in pediatric consultations. In winter, colds, flu, pharyngitis, otitis, sinusitis, acute bronchitis, bronchiolitis, chronic bronchitis, asthma, and pneumonia increase; in autumn, acute bronchitis, and acute asthma. These diseases affect mainly children and patients with respiratory allergies. The decline in temperature in winter leads to congestion of the nose, sinuses, and ears and weakens the body's resistance to infection, leading to common cold symptoms, such as nasal obstruction, facial pain, runny nose, and sneezing[10-11].

This research evaluates the population's health risk according to the climate seasonality, favoring the planning and implementation of health actions. By identifying a seasonal periodicity in those diseases, prophylactic measures can be implemented to minimize the intensity of the occurrence of registrations for this type of morbidity[8].

Pneumonia, bronchitis/bronchiolitis, and asthma are the three leading causes of hospital admissions in children, and they are the diseases most likely to be influenced by weather variables.

## OBJECTIVES

To analyze the climate seasonality of respiratory diseases in children aged 0-9 years and to present a model to predict hospital admissions for 2021 to 2022.

## METHODS

### Ethical aspects

This research presents data from secondary sources and follows Resolution n° 466/2012 and Resolution n° 510/16 of the National Health Council. The studies using public access information are exempt from prior approval by the CEP/CONEP system. These data were used exclusively for this study, and the information was prepared collectively so the results avoid reference to any individual and did not intend any harm to the persons or institutions involved.

### Design of study

Observational cohort study guided by the STROBE tool. Based on data on exposure and frequency of pneumonia, bronchitis/bronchiolitis, and asthma, it was analyzed the seasonal effect of the number of registered cases and performed an adjustment in the seasonal autoregressive integrated moving average (SARIMA) models in the registered cases of these diseases. After adjusting the SARIMA, each model was used to verify the potential use for forecasting.

### Period and place of study

This research was conducted in Campina Grande, in the State of Paraíba (PB), with data covering 23 years (from January 1998 to December 2020). The city of Campina Grande is at an average altitude of 555 meters above sea level, -7.23° latitude and -35.88° longitude. The municipality's area is 593.026 km$^2$, with an estimated population of 407,754 inhabitants, according to data from the Brazilian Institute of Geography and Statistics (IBGE, 2018). It has a climate with more moderate temperatures, considered "tropical dry season." The rainy season starts in April/May and ends in August/September[12].

### Population or sample

The study population consisted of hospitalized children of both genders, aged 0-9 years, diagnosed with pneumonia, bronchitis/bronchiolitis, asthma, and respiratory diseases affecting the lower airways. The SUS Computer Department (Datasus), a platform that provides public domain health data from health institutions participating in the Unified Health System (SUS), filtered the data. The data employed in this study considered only the residents of Campina Grande since hospitals in this city serve populations of neighboring cities.

### Criteria of inclusion and exclusion

The inclusion criteria were hospital charts of children aged 0-9 years of both genders admitted with pneumonia, bronchitis/bronchiolitis, and asthma in hospitals in Campina Grande (PB).

Hospital charts of children not residing in the city of Campina Grande were excluded.

### Study protocol

Data from pneumonia, acute bronchitis/bronchiolitis, and asthma admissions were obtained from the SUS-Datasus computer department through the Hospital Information System (*Sistema de Informações Hospitalares*-SIH) requiring tabulation and systematization in spreadsheets and other conversion tools, such as the TAB Win 32 software. Subsequently, the data were organized and analyzed monthly in Box Plot distributions to check seasonality, and then the SARIMA models were adjusted for each morbidity. After the calibration of those models, it was possible to predict the occurrence of new cases of morbidities.

### Analysis of results and statistics

In the sequence of the analyses, we obtained the SARIMA models for the dependent variables "pneumonia," "bronchitis/bronchiolitis," and "asthma." Seasonal behavior can be identified in many temporal series, especially in climate data, or strongly influenced by climate[13]. In a classical temporal series model, it was assumed that the temporal series could be the sum of three components: trend, seasonality, and randomness. (Equations 1 and 2).

$$Z_t = T_t + S_t + a_t \quad ,t = 1,\ldots,n \ (1)$$
$$Z_t = T_t \times S_t \times a_t \quad ,t = 1,\ldots,n \ (2)$$

*T* is the trend component at instant *t*; *S* is the seasonal component at instant *t*, and *a* is a random term.

Equation 1 (additive process) is recommended when seasonality does not depend on the trend and randomness, while Equation 2 (multiplicative process) is recommended if seasonality varies with the trend. In the case of data of admissions due to the diseases, an alternative approach should be considered, taking into account stochastic seasonality, when a homogeneous seasonal pattern is not observed in time, although present, but with different plateaus and abrupt trends throughout the series. In these cases, we suggest the application of SARIMA models utilized in this research[14-15].

SARIMA models check autocorrelation of temporal series values at successive instants, i.e., it correlates the variable of a given month ($Var_t$)) with its value observed in the previous month ($Var_{t-1}$) until verifying autocorrelation for a seasonal season[16].

The criterion for selecting the best SARIMA model for each disease was based on Akaike's information criterion (AIC), a quality measure for a statistical model for a given group of data. Based on information entropy with a coefficient of goodness of fit and the complexity of the data. *AIC* is defined in Equation 3, where $L_p$ is the maximum likelihood function of the model, and *p* is the number of explanatory variables considered in the model[17].

$$AIC_p = -2log(L_p) + 2[(p+1)+1] \ (3)$$

The results indicated that models of this nature fit the data well and have considerable predictive power.

After verifying the seasonality of pneumonia, bronchitis/bronchiolitis, and asthma cases and the subsequent adjustment of the SARIMA model, we obtained the prediction of new cases of the morbidities mentioned before for 2021 and 2022.

## RESULTS

From 1998 to 2020, there were 37,026 admissions for pneumonia, bronchitis/bronchiolitis, and asthma. From those, 24,325 with pneumonia (66% of the admissions), 10,115 admissions due to asthma (27%), and 2,586 reports of admissions with bronchitis/bronchiolitis (7%).

The box-plot graphics show the seasonality in the incidence of cases registered for all diseases, with the highest number of registrations between the months of autumn and winter. Pneumonia occurs between April and July; bronchitis/bronchiolitis from May to August; and asthma from April to July (Figure 1 - a, b, c). This behavior is very similar to the period of higher rainfall, which is associated with lower temperatures, higher relative humidity, lower insolation rate, reduced wind speed, and increased atmospheric pressure.

Values considered discrepant to the distribution or outliers were not observed in the temporal asthma series (Figure 1-c) but were detected in more numbers and happened in all months with bronchitis/bronchiolitis (Figure 1-b) and fewer numbers due to pneumonia (Figure 1-a). Those results indicate that the cases of bronchitis/bronchiolitis present the most significant variability concerning the population mean.

Analyzing these admissions by age group related to pneumonia, we found 6,572 cases in the age group 0-12 months (29.5%); 11,058 admissions in the age group 1-4 years (49.8%); 3,443 admissions in the age group 5-9 years (15.5%). 5,569 admissions were registered with acute bronchitis/bronchiolitis: 3,510 in the age group 0-12 months (63.02%); 1,654 in the age group 1-4 years (29.7%); and 405 in the age group 5-9 years (7.2%). There were 9,701 admissions due to asthma, of which 1,588 in the age group 0-12 months (16.3%); 5,690 in the age group 1-4 years (58.6%); and 2,423 in the age group 5-9 years (24.9%).

The years presenting the highest hospital admissions for pneumonia cases were 1998 and 1999, with 2,029 and 1,953 cases, respectively. Children with the most admissions were in the age group 1-4 years. The months with the most registrations were May (2,487 admissions) and June (2,485 admissions).

In the cases of bronchitis/bronchiolitis, the years with the highest incidence were 2001 and 2000, with 893 and 727 admissions, respectively. The age group 1-4 years had the highest number of cases in 2001, and 0-12 months in 2000. June (664) and July (648) were the months that presented the highest occurrences.

Regarding asthma registrations, the highest number of admissions occurred in 2002 and 2010, with totals of 807 and 810 registrations, respectively. The age group 1-4 presented the highest number of admissions in those two years, and the months with the highest number of admissions were May and June.

In Campina Grande (PB), the cases of pneumonia have been decreasing over the past 23 years (Figure 2 - a), a fact that may be associated with the city's promotion and prevention actions, avoiding the incidence of the disease that usually results in hospital admissions. There was a reduction from 2,029 cases in 1998 to 679 cases in 2017. The year 2017 showed an increase in the occurrence of bronchitis/bronchiolitis (Figure 2 - b). Regarding asthma, there were 737 cases in 1998 and 219 in 2017. Like pneumonia, there was a reduction in asthma cases during the period of the study[21-22]. The reason may lie in the consolidation of the national asthma control program (Figure 2 - c). The trend line in the graphs shows more abrupt declines in the number of cases of pneumonia and asthma than of bronchitis/bronchiolitis, which has a precise bimodal distribution with two nuclei of concentration: the first containing the largest number of registrations from 2000 to 2008; and the second, less intense, from 2013 to 2019 observation between 2021 and 2022.

Figure 3 (a) shows that the SARIMA model predicts a continuity of the downward trend in the number of cases of pneumonia in Campina Grande, with less than 50 cases/year. For bronchitis/bronchiolitis (Figure 3 - b), the model indicates the same trend found between 2009 and 2012 when registered cases of this disease in the city did not exceed 30 occurrences/year, but with a slightly positive trend in 2022, a fact that may be associated with the absence of a specific vaccine against its primary causative agent, the respiratory syncytial virus.

In asthma cases, the predictive model highlights the downward trend in admission rates over the years; however, it linearizes the predicted number of admissions by the recent average data for the years 2021 and 2022 (Figure 3 - c), without variability in the occurrence rate of asthma admissions in children under nine years old in Campina Grande (PB).

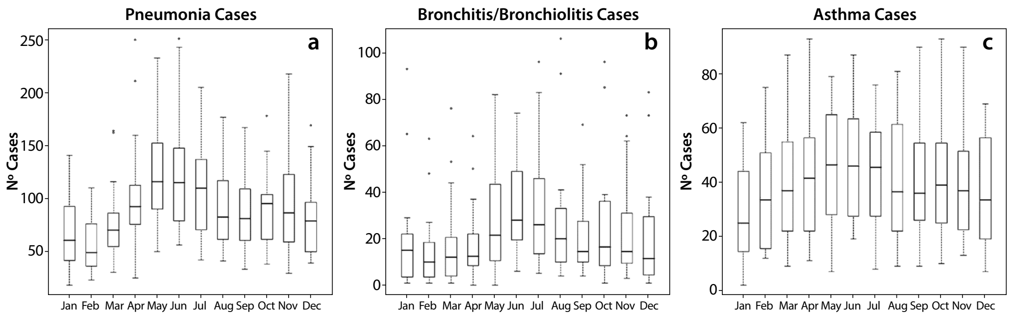


**Figure 1** – Box-Plot charts showing monthly distribution of reported cases of pneumonia (a), bronchitis/bronchiolitis (b) and asthma (c), Campina Grande, Paraíba, Brazil, between 1998 and 2020

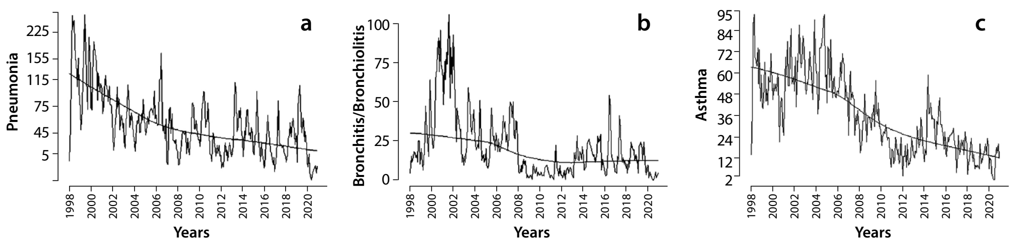


**Figure 2** - Distribution of the number of cases and respective trend lines for pneumonia (a), bronchitis/bronchiolitis (b) and asthma (c) in children under 9 years old from 1998 to 2020, Campina Grande, Paraíba, Brazil

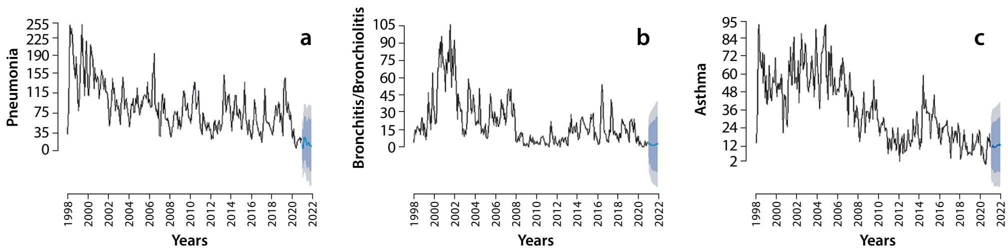


**Figure 3 –** Temporal variation for the period 1998 to 2020 and prediction of pneumonia (a), bronchitis/bronchiolitis (b) and asthma (c) cases for the period 2021 to 2022, Campina Grande, Paraíba, Brazil

The SARIMA models were adjusted in the cases of pneumonia, bronchitis/bronchiolitis, and asthma in Campina Grande (PB) (Table 1). In the variable "pneumonia," the best-adjusted SARIMA model has the configuration AR(3), D(1), and MA(3), with parameters $p = 3$, $d = 1$, and $q = 3$. $p$ represents the number of autoregressive terms, $d$ is the number of differentiations required for series stationarity, and $q$, the number of moving average terms. Thus, the model that better represents the pneumonia temporal series is a SARIMA (3,1,3) equivalent to an ARIMA (3,1,3) model with seasonality (1,0,0). In the variable "bronchitis/bronchiolitis," was adjusted a better configuration of the SARIMA model with AR(4), D(1), and MA(4), with parameters $p = 4$, $d = 1$, and $q = 4$. Note that the model that better represents the series of the variable "bronchitis/bronchiolitis" is a SARIMA (4,1,4) equivalent to an ARIMA model (4,1,4) with seasonality 0,0,2, respectively. And, in the variable "asthma", we found that the SARIMA model identified with the configuration AR(1), D(1), and MA(2), with parameters $p = 1$, $d = 1$, and $q = 2$, is the one that best represents the series in the variable "asthma," i.e., a SARIMA (1,1,2). These models were selected for each morbidity because, among the competing models, they had the lowest value of the AIC (Akaike Information Criterion) parameter (Table 1).

After adjusting the SARIMAs, each model was used to verify the potential for use in forecasting. They were processed and validated for the last three years of each disease series, simulating the

**Table 1** – Results of the SARIMA model with seasonality for cases of pneumonia, bronchitis/bronchiolitis, and asthma, Campina Grande, Paraíba, Brazil

| Models | p | d | Q | σ² | AIC |
|---|---|---|---|---|---|
| M1 SARIMA (3.1.3) (1.0.0) | 3 | 1 | 3 | 557.8 | 2.201.4 |
| M2 SARIMA (4.1.4) (0.0.2) | 4 | 1 | 4 | 4432.4 | 1.527.7 |
| M3 SARIMA (1.1.2) (0.0.2) | 1 | 1 | 2 | 126.2 | 1.840.6 |

## DISCUSSION

The monthly variation of pneumonia morbidity in infants, children, and adults was observed in a study conducted in the municipality of Campo Grande, State of Mato Grosso do Sul (MS), during the period from 2004 to 2008[18]. An increase in morbidity happened over the winter months and the month before, i.e., May and August. There was also a decrease in pneumonia morbidity in the warmer months (January, February, November, and December).

A study showed the association between environmental variables and respiratory diseases (asthma and bronchitis) in children in Macapá, State of Amapá (AP), from 2008 to 2012. Cases of asthma were more frequent in the rainy season (December to May), corresponding to 51% of registrations; In the incidence of bronchitis, the highest frequency was in the dry season, from June to November[19]. Research showed that, in the rainy season, there is an increase in asthma cases, whereas, in the dry season, there is a decrease in registrations of this disease.

The influence of climate variation in Cuiabá, in the state of Mato Grosso (MT), triggered health services to treat asthma in children under five years old[20]. The most affected age group was 1-3 years. It was also observed that, during the rainy season, the percentage of asthma outpatient visits was higher than during the dry season; however, the frequency of asthma hospitalizations was higher in the dry season.

In Campina Grande (PB), the cases of pneumonia have been decreasing over the past 23 years (Figure 2a), a fact that may be associated with promotion and prevention actions in this city, preventing the occurrence of the disease which usually results in hospital admissions. This reduction was from 2,029 cases in 1998 to 679 cases in 2017. For bronchitis/bronchiolitis (Figure 2b), the year 2017 showed an increase in the occurrence of this type of morbidity. For asthma cases, in 1998 were 737 cases, and in 2017, 219 cases; and, like the pneumonia cases cited above, there was a decrease during the study period[21-22]. Possibly, part of asthma cases decrease over the years may be due to the consolidation of the national asthma control program (Figure 2c).

Cases of pneumonia showed a reduction in the behavior over the years under study. Therefore, it is essential to highlight that, after applying the prediction model for the years 2021 to 2022, as shown in Figure 3 (a), we point out a tendency to a decrease in cases of admissions because of pneumonia in children under nine years old in Campina Grande (PB), corroborating what has been happening in the last 23 years.

This fact may be associated with the implementation in 2010 of the 10-valent pneumococcal conjugate vaccine. Brazil's basic childhood immunization schedule started to make it available in health centers, for free, for children from 2 months to 2 years old. Another protection offered in the immunization calendar that helps prevent pneumonia is the influenza vaccine, against influenza, accessible through annual mass immunization campaigns[23].

### Study limitations

The application of data from Datasus associated with the statistical prediction model serves various purposes: the evaluation of health situations, health services, and planning and management of hospital services, among others. However, the use of data from this platform has some limitations, such as data underreporting, hospital admissions financed only by SUS, generation of new authorizations for hospital admissions in cases of transfers to another hospital, and non-available patient's comprehensive individual information, among others.

### Contributions to the field of Nursing

Public health managers can make use of the prediction model to organize the health services and, thus, receive a significant number of patients (children) with increased human resources and infrastructure, avoiding overcrowding and low-quality care in periods with more registration of cases. That is in line with the suggestion of the World Health Organization, which encourages the creation of models capable of predicting an increase in diseases because if they show good accuracy, they can be of great value in combating and preventing epidemics, thus organizing health services and other sectors to meet the population's needs or expectations.

## CONCLUSIONS

Seasonality is noticeable in the cases of morbidities in this study, with the highest number of registrations between autumn and winter.

A predictive model based on seasonal models of the SARIMA family was developed to estimate the number of admissions for pneumonia, bronchitis/bronchiolitis, and asthma. After checking similarities between the seasonality of the diseases and meteorological variables, it was corroborated the climate influence on the incidence of these diseases.

The predictive model was employed to generate forecasts for 2021 to 2022 and found the continued downward trend in pneumonia admissions, confirming what has been happening over the last 23 years. In the cases of bronchitis/bronchiolitis, the prediction model showed variability in admission rates, with a slightly positive trend. In cases of asthma, there was no variation in the admission occurrence rates.

## SUPPLEMENTARY MATERIAL

Article extracted from the doctoral thesis "Prevalent respiratory morbidities in hospitalized children and the influence of meteorological variables", presented to the Federal University of Campina Grande, Campina Grande, PB, Brazil.

The thesis is available in the repository of Theses and Dissertations of the Graduate Program in Engineering and Natural Resources of the Federal University of Campina Grande and can be accessed through the following link: http://www.recursosnaturais.ufcg.edu.br /index.php/thesis.

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