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Influence of meteorological variables on the occurrence of pneumonia

Influência de variáveis meteorológicas na ocorrência de pneumonia

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Abstract

The causes of the influence of weather and climate on living beings are not completely known, so studies that relate them to human health and strategies related to the formulation of public health policies are of great importance. This study aimed to analyze the influence of meteorological variables (precipitation, temperature and relative humidity) and the number of cases affected by pneumonia in the city of Campina Grande, PB in the period from 1998 to 2016. To this end, an epidemiological, retrospective and descriptive study with a quantitative approach was carried out. The main contributions are configured as essential factors to understand the consequences that changes in climate variables can have on the health of the population of the studied municipality. As a recommendation, it stands out the limitation of the study that relates to underreporting of the diseases, incorrect diagnoses, among others, that may occur with the responsible departments for providing health information.
Keywords: Climate Health. Meteorological Variables.

Resumo

As causas da influência do tempo e do clima sobre os seres vivos não são completamente conhecidas, logo é de grande importância os estudos que os relacionam com a saúde humana e as estratégias relacionadas à formulação de políticas públicas de saúde. Esse estudo objetivou analisar a influência das variáveis meteorológicas (precipitação, temperatura e umidade relativa do ar) e o número de casos acometidos por pneumonia no município de Campina Grande, PB no período de 1998 a 2016. Para tanto, foi realizado um estudo epidemiológico, retrospectivo e descritivo com abordagem quantitativa. As principais contribuições configuram-se como fatores essenciais para compreender as consequências que as mudanças nas variáveis climáticas podem ocasionar na saúde da população do município estudado. Como recomendação, destaca-se a limitação do estudo que se relaciona às subnotificações das doenças, diagnósticos incorretos, dentre outros, que podem ocorrer junto às repartições responsáveis pelo fornecimento de informações de saúde.
Palavras-chave: Clima. Saúde. Variáveis meteorológicas.

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1 INTRODUCTION

Concerns about the environmental issue and its relations have been inserted in Public Health since its beginnings, although it was only in the second half of this century that it was structured as a typical area to address, debate and discuss these issues in order to identify interrelationships between health and environment, now being called by the World Health Organization (WHO) as Environmental Health.

Thus, in its broadest definition, the field of environmental health encompasses the area of public health related to scientific knowledge and the formulation of public policies related to the interaction between human health and the creation and implementation of environmental health surveillance programs in several countries in the world, including Brazil (BRASIL, 2010).

However, it is understood that climate change directly interferes in the environment, putting at risk the ecological balance of the planet, influencing, among other things, the emergence of diseases and the quality of life of the population.

In the last decades, the study of the effects of climate on the health of the population has been disseminated and discussed by the media, institutions, researchers and specialists from different areas of knowledge. Changes in meteorological elements, such as temperature and relative humidity and precipitation, can bring greater abundance and dissemination of vectors and pathogens. Therefore, the climate anomalies associated with such phenomena tend to be catastrophic and cause social, economic and environmental damage.

The causes of the weather and climate influence on living beings are not completely known, so studies that relate them to human health and strategies related to the formulation of public health policies are of great importance. Notably, the respiratory diseases are very common and the ways of contracting them are also very comprehensive, so it is essential to carry out regionalized studies, in addition to identifying possible factors, such as climate change. In this sense, the discussion of this subject has been broadened by professionals from the most varied areas, so that relationships between the alteration of meteorological variables and the emergence of diseases are established.

The importance of researching the conditions responsible for the manifestation of respiratory diseases, especially pneumonia, stems from the fact that this disease is directly or indirectly influenced by meteorological and socio-environmental elements (climate, urbanization and the population's way of life).

The WHO reported that pneumonia kills the most children under five, with an estimated 1.2 million worldwide, more than deaths from AIDS, malaria and tuberculosis combined. Of these deaths from pneumonia, more than 99% would be registered in developing countries like Brazil, which is why the WHO has reinforced the request to these governments to give priority to preventing and combating the disease. According to this organization, pneumonia is one of the most likely problems to be solved in the global health scenario (WHO, 2014).

In this regard, climate variables have generated growing concern regarding the potential effects on human health, especially those related to communicable diseases, as they are an important cause of morbidity and mortality and afflict millions of people in different regions of the world, especially in underdeveloped countries.

Constituting climate variations, a huge contributor to the aggravation of diseases, the knowledge of meteorological conditions favors the prevention of damage to society, whether material or human. However, it is understood that climate change directly interferes in the environment, putting at risk the ecological balance of the planet, influencing, among other things, the emergence of diseases and the quality of life of the population.

There have been several studies that seek to investigate this theme, whether at the national (SILVA JÚNIOR, 2011; MURARA, MENDONÇA & BONETTI, 2013; COSTA *et al.* 2014; SILVA *et al.* 2016; SANTOS *et al.* 2016; PONTES *et al.* 2016; MANDÚ *et al.* 2019), or international level (SALVI, 2007; OLULEYE & AKINBOBOLA, 2010; RUDAN *et al.* 2013; QIU *et al.* 2016 ; GHALHARI & MAYVANEH, 2016) that demonstrate its relevance for understanding the conditions related to climate variables and cases of pneumonia reinforcing the importance to strengthen regionalized studies in specific geographical contexts and contribute to the management and formulation and public policies that can minimize social, economic and environmental impacts of the population.

In this perspective, the present study seeks to answer the following question: What is the influence of the meteorological variables (temperature and relative humidity and precipitation) and the incidence of pneumonia in the city of Campina Grande, PB?

This study aimed to analyze the influence of meteorological variables (precipitation, temperature and relative humidity) and the number of cases affected by pneumonia in the city of Campina Grande, PB in the period from 1998 to 2016.

2. ‘LITERATURE REVIEW

2.1 Interactions between Climate, Environmental Health and Human Health

According to the Health Surveillance Secretariat of Ministry of Health, in Normative Instruction 01/05, Environmental Health comprises the area of public health related to scientific knowledge and the formulation of public policies related to the interaction between human health and factors of the natural environment and anthropogenic that determine it, condition it, in order to improve the quality of life of the human being from the point of view of sustainability (MOTA, 2013).

For Mota (2013), environmental health is, therefore, the area of public health that considers the effects that the environment can have on the physical, mental and social well-being of the human being, in other words, that associates the conditions of the environment to the population health.

According to Amorim *et al.* (2013) for a long time, studies have correlated with the influence of the environment on the human organism, trying to understand the complex process of health and disease, resulting from the society´s action facing the appropriation of nature and organization of space.

Among all the concerns about the impacts caused by the environmental degradation, the most complicated one involves the loss of the population's quality of life. Thus, it is understood that the concern with weaving relationships between environment and health refers much more to trying to make complaints about the quality of life and demonstrating that the climate is just one variable, and that today, diseases, before any other factor, are socially determined.

A great instrument for obtaining the most varied forms of knowledge is meteorology and climatology, allowing humanity a previous understanding of the past and present about the climate and its dynamics (CONCEIÇÃO *et al.,* 2015).

The climate, among other factors, can cause the manifestation of certain health diseases through their properties (temperature and relative humidity, rainfall, atmospheric pressure and winds), which interfere in people's well-being (SANTOS *et al.,* 2016).

To this end, the WHO data (2015) point out that the climate has a fundamental role in the transmission of several diseases that are among the main causes of morbidity and mortality in the world. Being an important agent for the spread of several diseases, meteorological variables (air temperature, rainfall and relative humidity) are important objects of investigation.

According to Rouquayrol and Almeida Filho (2013) in the epidemiological field, climate is the aspect of the physical environment that has so far focused most attention on epidemiological studies, being the result of a variety of specific meteorological phenomena, which characterize the average situation of the atmosphere, in a delimited region of the Earth's surface. Climate factors are studied to, through them, hypotheses of causality can be inferred as to any risk factor whose variation in nature depends on the variation of some climate factor.

According to Ayoade (2010), some diseases tend to be prevalent in certain climate zones, while others, particularly contagious infections, tend to follow a seasonal pattern in their incidence.

The variables, precipitation, temperature and relative humidity of the air were selected for analysis, as they are unstable elements of the atmosphere and according to Ayoade (2010) the influence on human health can be direct, indirect, positive or negative. However, to study health it is necessary to analyze, from other perspectives, the context in which the individual is inserted. Checking the relationship between it and nature, the basic conditions of housing, education and health, which is directly related to health problems. National studies have found positive associations between climate conditions and respiratory diseases (MOURA *et al.,* 2008; CASTRO *et al.,* 2009; SOUSA *et al.,* 2012). At the international level, we also find some efforts (SALVI, 2007; XU *et al*., 2011).

In Brazil, there are several studies correlating the influence of the environment on the human organism (NATALI *et. Al*., 2011; SOUZA *et al*., 2014; PONTES *et al*., 2016), trying to understand the complex health and disease process that assessed the impacts of climate and weather conditions on the health of the population. Below are several of these studies that addressed these environmental variables and the adverse effects on the population's health.

Gouveia *et al.,* (2003) carried out a study in which they analyzed these impacts in the two largest Brazilian cities, Rio de Janeiro (RJ) and São Paulo (SP). Nascimento *et al.,* (2006) estimated in São José dos Campos (SP) the association of hospitalizations for pneumonia with the increase in air pollutants. The study confirms that the harmful potential of air pollutants on health can also be detected in medium-sized cities. The magnitude of the effect was similar to that observed in the city of São Paulo. In addition, it shows the high susceptibility of children to adverse effects arising from exposure to atmospheric contaminants.

Natali *et al*., (2011) described the main characteristics of temporal distribution, by age group and by specific cause, of hospital morbidity due to respiratory diseases in childhood and adolescence in the city of São Paulo, SP, from the records of hospitalizations in hospitals of the Unified Health System (SUS), from 2000 to 2004. They found that hospitalizations for respiratory diseases (pneumonia, bronchopneumonia and asthma) of children and adolescents show a distribution pattern dependent on the age group and seasonality. The smaller the age group, the greater the number of hospitalizations

Alves *et al.,* (2015), in turn, evaluated the effects of climate variables (rainfall, air temperature average and relative humidity) on the incidence of diseases related to upper airway infections (UAI) in municipality of Monteiro - PB. The results showed that the maximum values for the number of UAI records occur in the autumn-winter period (March to August) and minimum values in the spring-summer period (September to February).

Azevedo *et al.,* (2015) evaluated the influence of climate variables (rainfall, temperature and air humidity) on the incidence of acute respiratory infections (ARI) in children under two years of age in the municipalities of Monteiro and Campina Grande, in Paraíba, from 1998 to 2012.

Pontes *et al.,* (2016) evaluated respiratory diseases in relation to some climate variables (air temperature, rainfall and relative humidity) in the municipality of Ponta Grossa, PR, from January 1998 to December 2013. It was possible to observe a great relevance of pneumonia in the hospitalization rates. Among these climate variables, the one that was most correlated with pneumonia was the minimum temperature with high statistical significance.

Miranda (2016) investigated the association of meteorological elements (minimum relative humidity and maximum and minimum daily temperatures) with hospitalizations for respiratory morbidities (pneumonia and flu) in the city of São Paulo, SP. They observed a certain tendency towards an increase in hospitalizations when there was an increase in maximum and minimum temperatures, and a decrease in minimum relative humidity in up to seven days before peak hospitalization.

Azevedo *et al.,* (2017) evaluated the effects of seasonal climate variations on the occurrence of hospitalizations for respiratory diseases due to *Influenza* and Pneumonia in the elderly population of the Metropolitan Region of João Pessoa in the State of Paraíba. It was found that the largest peaks in hospitalizations for pneumonia occur in autumn and winter. Therefore, suggesting an association between cold and hospitalizations for pneumonia.

Mandú *et al.* (2019) evaluated and compared the effect of temperature and relative humidity on the occurrence of respiratory diseases in the following Brazilian cities: Fortaleza, Manaus, Natal and Palmas. For this, monthly data of temperature and relative humidity of the air were used, registered by conventional meteorological stations allocated in the capitals mentioned above, made available by the Meteorological Database for Teaching and Research (BDMEP). The results show a significant inverse association in Fortaleza and Natal, and a direct one in Manaus and Palmas with the average air temperature, and for the relative humidity, since they showed an association.

At the international level, there are also several experiences that sought to study the association between health and climate. Weber *et al.,* (1988) who carried out a study in The Gambia, from 1993 to 1996, in children under two years old hospitalized with respiratory infections. The authors concluded that hospitalizations occurred more frequently in the months of July to November during the rainy season.

Strachan and Sanders (1989) evaluated wet housing and childhood asthma and the respiratory effects of indoor air temperature and relative humidity. The results found were contrary to the widespread belief that internal temperature and humidity are important determinants of respiratory health, although they do not directly exclude the effects caused by mites or molds, whose survival is determined by the humidity of their respective microenvironments.

Chan *et al.,* (1999) conducted a study in Hong Kong, from 1993 to 1997, in 9635 children hospitalized with acute respiratory infections. The authors concluded that the peaks in the incidence of infections occurred from April to September and were related to rainfall, low temperatures and high relative humidity.

Oluleye and Akinbobola (2010) studied the relationship between pneumonia infection, precipitation and air temperature in Lagos, Nigeria. They found that the significant climate change was detected in both precipitation and air temperature. They concluded that climate parameters, rainfall and air temperature have a profound influence on the occurrence of pneumonia and are directly responsible for the intractable increase in disease. Xu *et al.,* (2011) investigated the epidemiological characteristics of *Mycoplasma Pneumoniae* (MPP) in childhood and observed whether there is a relationship between epidemiological characteristics and meteorological factors in Hangzhou, China. The study showed that the MPP rate was higher in older children than in younger ones. Girls had a higher positive MPP rate than boys. In Hangzhou, MPP was more prevalent in summer and fall. Air temperature was the only meteorological factor that affected the prevalence of MPP.

Xu *et al.,* (2014) examined the impact of temperature on childhood pneumonia in Brisbane, Australia. They found that children aged 2-5 years old and female children were particularly vulnerable to the impacts of heat and cold, and indigenous children were sensitive to heat. Hot and cold waves had significant added effects on childhood pneumonia and the magnitude of these effects increased with intensity and duration. There have been changes over time in the main and added effects of temperature in childhood pneumonia. Children, especially female and indigenous children, must be particularly protected from extreme temperatures. They concluded that the future development of early warning systems should take into account the change over time in the impact of temperature on children's health.

Chen *et al.,* (2014) used the meteorological variables precipitation, temperature and relative humidity in the occurrence of Legionnaires' disease (LD) in Taiwan in the period 1995-2011. Legionnaires' disease (DL) is an acute form of pneumonia, and climate change is considered a plausible risk factor. And an increase in daily rainfall is likely to be a critical climate factor that triggers the occurrence of this type of disease, where the risk is particularly significant. In addition, stratified analysis also showed that positive associations of precipitation with LD incidence were only significant in male and elderly groups and during the hot season.

Qiu *et al.,* (2016) analyzed the association between room temperature and pneumonia in the elderly and assessed the disease burden attributable to cold and hot temperatures in Hong Kong, China. Subgroup analysis was performed to examine the gender gap. They concluded that most of the temperature-related load for hospitalizations for pneumonia in Hong Kong was attributable to cold temperatures, and elderly men were more susceptible.

As noted, there are several studies that have analyzed the effect of climate variables (air temperature, relative humidity and precipitation) on respiratory diseases, showing the relevance of carrying out this research. Consequently, it is understood that assessing the selection of these climate variables in the incidence of pneumonia cases in the city of Campina Grande, PB presents itself as a gap that can contribute to the management of local health and the development of public health policies.

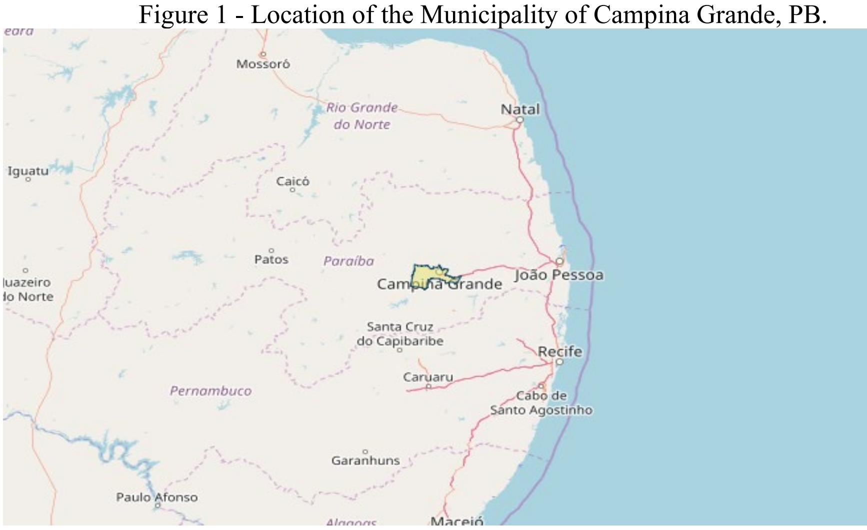
3 MATERIAL AND METHODS

3.1 Study area and period

The study was carried out in the Municipality of Campina Grande, located in the State of Paraíba, during the historical series from January 1998 to December 2016, corresponding to 19 years.

The municipality of Campina Grande (Figure 1) is located in the dry countryside of Paraíba. It has a tropical weather with moderate temperatures. It rains much more in summer than in winter. The climate classification according to Köppen and Geiger has an average temperature around 22.9° C, reaching 32ºC on the hottest days and 15ºC on the coldest nights of the year. The annual rainfall average 765 mm. The relative humidity of the air is between 75 to 83%. The rainy season starts in April and ends in August (TRAVASSOS, 2012).

Figure 1 - Location of the Municipality of Campina Grande, PB.



Source: IBGE (2017).

3.2 Type of Study and Statistical Treatment

A retrospective, epidemiological, descriptive, cross-sectional study was carried out in order to identify and analyze a possible relationship between cases of pneumonia and meteorological variables (rainfall, air temperature and relative humidity) in the context of the municipality of Campina Grande, Paraíba.

As for nature, it is classified as quantitative, since the cases of hospitalization due to pneumonia and their possible relations with the research variables were analyzed.

The statistical treatment was composed by the measures of association, ***r*** by Pearson, to verify the correlation between cases of pneumonia with the environmental variables (temperatures, relative humidity and precipitation) in the respective region of the study. To perform the Pearson Correlation test, meteorological variables were considered as independent variables and, as dependent variables, pneumonia. The dependent variable is what happens during an investigation to measure the health-disease condition (outcome) and the independent variable is the factor that precedes the outcome (exposure), as advocated by Callegari-Jacques (2009) and Franco (2017).

4 RESULTS AND DISCUSSION

Below the results found when crossing the meteorological variables and the age range of cases of pneumonia in Campina Grande during the years 1998 to 2016 are presented.

4.1 Correlation of cases of pneumonia with meteorological variables by age group in Campina Grande, PB.

Table 1 shows the values of Pearson's correlation coefficients (***r***) and Determination (R^2) found between the meteorological variable precipitation and the number of cases of pneumonia that occurred in Campina Grande in the years 1998 to 2016.

Table 1 - Correlation between cases of pneumonia and precipitation in Campina Grande

Years	<5 y.old			Between 5 and 19 y. old			Between 20 and 59 y. old			Over 60 y.old		
	r	R²	Classif.	r	R²	Classif.	r	R²	Classif.	r	R²	Classif.
1998	0,35	0,12	Medium	0,39	0,16	Medium	0,55	0,3	Medium	0,70	0,5	Strong
1999	0,02	0,00	Null	-0,16	0,03	Weak	0,11	0,01	Weak	-0,01	0,00	Null
2000	0,44	0,19	Medium	0,01	0,00	Null	0,36	0,13	Medium	-0,28	0,08	Weak
2001	-0,03	0,00	Null	-0,44	0,19	Medium	-0,64	0,41	Strong	-0,63	0,40	Strong
2002	0,85	0,71	Strong	0,31	0,10	Medium	0,30	0,09	Weak	0,21	0,05	Weak
2003	0,23	0,05	Weak	-0,20	0,04	Weak	-0,13	0,02	Weak	0,00	0,00	Null
2004	-0,45	0,20	Medium	-0,90	0,81	Strong	-0,56	0,32	Medium	-0,24	0,06	Weak
2005	-0,11	0,01	Weak	-0,56	0,31	Medium	0,02	0,00	Null	-0,05	0,00	Null
2006	0,46	0,21	Medium	0,18	0,03	Weak	0,02	0,00	Null	-0,14	0,02	Weak
2007	0,37	0,13	Medium	-0,04	0,00	Null	0,09	0,01	Weak	0,32	0,10	Medium
2008	-0,21	0,04	Weak	-0,21	0,05	Weak	-0,05	0,00	null	0,20	0,04	Weak
2009	0,03	0,00	Null	-0,44	0,19	Medium	-0,39	0,15	Medium	-0,29	0,08	Weak
2010	0,51	0,26	Medium	-0,40	0,16	Medium	-0,30	0,09	Weak	-0,11	0,01	Weak
2011	0,55	0,30	Medium	-0,36	0,13	Medium	0,18	0,03	Weak	0,09	0,01	Weak
2012	0,11	0,01	Weak	0,24	0,06	Weak	0,31	0,09	Weak	0,44	0,20	Medium
2013	0,53	0,28	Medium	0,35	0,12	Medium	0,42	0,18	Medium	0,46	0,21	Medium
2014	0,62	0,39	Strong	-0,22	0,05	Weak	0,27	0,08	Weak	0,11	0,01	Weak
2015	0,62	0,39	Strong	-0,22	0,05	Weak	0,27	0,08	Weak	0,11	0,01	Weak
2016	0,15	0,02	Weak	-0,11	0,01	Weak	0,44	0,20	Medium	-0,29	0,08	Weak

Source: Research data, 2017.

According to this for the age group of children under 5, the years 2002 (r = 0.85 and R² = 0.71), 2014 (r = 0.62 and R² = 0.39) and 2015 (r = 0.62 and R² = 0.39) showed an association between strong and medium regarding precipitation and the number of cases of pneumonia. The years 1998 (r = 0.35 and R² = 0.12), 2000 (r = 0.44 and R² = 0.19), 2004 (r = -0.45 and R² = 0.20), 2006 (r = 0.46 and R² = 0.21), 2007 (r = 0.37 and R² = 0.13), 2010 (r = 0.51 and R² = 0.26), 2011 (r = 0, 55 R² = 0.30), 2013 (r = 0.53 and R² = 0.28), except for the year 2004 (r = -0.45 and R² = 0.20), which presented a negative correlation behavior average, that is, when there is an increase in their respective values, there is a reduction in the hospitalization rate for the disease.

Note that the years 1999, 2001, 2003, 2005, 2008, 2009, 2012 and 2016 showed a weak and null correlation for the association of precipitation with cases of pneumonia in this age group. In practically more than half of the years of studies there was a correlation between medium and strong, reinforcing here the thesis that precipitation influences the cases of pneumonia within this age group. There are cases of asthma in the other age groups analyzed, so the most prevalent is the group under 5 years old.

For the age group between 5 and 19 years, the year 2004 (r = -0.90 and R² = 0.81) presented a strong negative correlation, demonstrating that 81% of cases of pneumonia in that year may have been influenced by the precipitation variable . The years that showed an average correlation were 1998 (r = 0.39 and R² = 0.16), 2002 (r = 0.31 and R² = 0.10), 2013 (r = 0.35 and R² = 0, 12). The years 2001 (r = -0.44 and R² = 0.19), 2005 (r = -0.56 and R² = 0.31), 2009 (r = -0.44 and R² = 0.19) , 2010 (r = -0.40 and R² = 0.16), 2011 (r = -0.36 and R² = 0.13), presented an average negative correlation. The years 1999, 2000, 2003, 2006, 2007, 2008, 2012, 2014, 2015 and 2016 showed a weak and null correlation. In the age group above 60 years of age, there is a very strong correlation between null and weak during 14 years showing that the explanation for these cases is unlikely.

When analyzing the data in Table 2, it is possible to observe that the correlation and determination coefficients point out over the years, the cases of pneumonia present a greater inverse correlation with air temperature, negative confirmation in the correlation coefficients and in the determination coefficients. There was a strong inverse correlation in nine years and an average in eight years, portraying the influence that this meteorological variable has in these specific cases. Therefore, the lower the temperature in this location, the greater the chances of presenting a greater number of pneumonia cases. Again, the age group under five years old prevails in relation to the others studied.

Note that the age group between 5 and 19 years old shows a strong inverse correlation in just three years: 1998 (r = -0.76 and R^2 = 0.57), 2001 (r = 0.78 and R^2 = 0.61), 2008 (r = -0.64 and R^2 = 0.41) and 2013 (r = -0.78 and R^2 = 0.61). In the age group between 20 and 59 years there were only three strong correlations, two of which were inverse (years 1998 with r = -0.78 and R^2 = 0.60 and year 2012 with r = -0.67 and R^2 = 0.44) and a direct one (2001 r = 0.74 and R^2 = 0.54). A similar result was obtained for the age group above 60 years old, which makes a total of 10 years with correlations classified between medium and strong and 9 years between null and weak.

Ayoade (2010) states that "some diseases tend to be preferred in certain climate zones, while some others, especially contagious ones, tend to follow a seasonal pattern". However, Martins and Trevisol (2013) emphasize that it is important to emphasize that, although it is perceived that outbreaks of respiratory infections are associated with low temperatures, they are not the cause of infections, they only influence the interactions between pathogens and hosts, increasing the chances of contamination.

The study's findings are in line with those found by Carneseca *et al.* (2010), Santos *et al.* (2016) where they showed that the number of hospitalizations for pneumonia in children up to 10 years old is influenced by the increase in temperature. Regarding the number of hospitalizations of elderly people over 75 years old due to this same cause, the study also spotted that it increases in the autumn period and decreases on weekends or when the minimum daily humidity of the air increases.

They also corroborate the statement by Brasil (2010) that the highest number of hospitalizations for pneumonia occurs at extreme ages, for children and the elderly over 60 years old. This is due to the weak immune system of people at these ages. In the elderly, this can be aggravated by the presence of other common diseases in old age such as diabetes, heart and kidney problems, among others.

Table 2 - Correlation between cases of pneumonia and precipitation in Campina Grande

Years	<5 years old			Between 5 and 19 y. old			Between 20 and 59 y. old			Over 60 y.old		
	r	R^2	Classif.	r	R^2	Classif.	r	R^2	Classif.	r	R^2	Classif.
1998	-0,51	0,26	Medium	-0,76	0,57	Strong	-0,78	0,6	Strong	-0,87	0,76	Strong
1999	-0,40	0,16	Medium	-0,40	0,16	Medium	-0,57	0,32	Medium	-0,54	0,29	Medium
2000	-0,51	0,26	Medium	-0,24	0,06	Weak	-0,46	0,22	Medium	0,31	0,09	Weak
2001	-0,63	0,39	Strong	0,78	0,61	Strong	0,74	0,54	Strong	0,31	0,09	Weak
2002	-0,65	0,42	Strong	0,22	0,05	Weak	0,39	0,15	Medium	0,34	0,12	Medium
2003	-0,72	0,52	Strong	0,17	0,03	Weak	-0,37	0,14	Medium	-0,51	0,26	Medium
2004	-0,13	0,02	Weak	0,44	0,19	Medium	-0,06	0,00	Null	-0,07	0,00	Null

Years	<5 years old			Between 5 and 19 y. old			Between 20 and 59 y. old			Over 60 y.old		
2005	-0,50	0,25	Medium	0,36	0,13	Medium	0,06	0,00	Null	-0,28	0,08	Weak
2006	-0,75	0,56	Strong	-0,48	0,23	Medium	-0,25	0,06	Weak	-0,48	0,23	Medium
2007	-0,64	0,40	Strong	-0,28	0,08	Weak	-0,11	0,01	Weak	-0,67	0,45	Strong
2008	-0,70	0,48	Strong	-0,64	0,41	Strong	0,02	0,00	Null	0,20	0,04	Weak
2009	-0,59	0,35	Medium	-0,21	0,04	Weak	-0,03	0,00	Null	-0,24	0,06	Weak
2010	-0,53	0,29	Medium	-0,30	0,09	Weak	0,29	0,08	Weak	0,04	0,00	Null
2011	-0,42	0,18	Medium	0,40	0,16	Medium	-0,34	0,12	Medium	-0,57	0,33	Medium
2012	-0,30	0,09	Weak	0,09	0,01	Weak	-0,67	0,44	Strong	-0,23	0,05	Weak
2013	-0,49	0,24	Medium	-0,78	0,61	Strong	-0,19	0,04	Weak	-0,67	0,45	Strong
2014	-0,69	0,48	Strong	0,05	0,00	Null	-0,37	0,13	Medium	-0,36	0,13	Medium
2015	-0,69	0,48	Strong	0,05	0,00	Null	-0,37	0,13	Medium	-0,36	0,13	Medium
2016	-0,77	0,60	Strong	-0,47	0,22	Medium	-0,30	0,09	Weak	-0,10	0,01	Weak

Source: Research data, 2017.

Table 3 contains the correlation coefficients (r) and the determination coefficients (R^2) of the meteorological element relative humidity of the air with pneumonia in the period from 1999 to 2009. There is a strong positive correlation in seven years with values of *r* oscillating between 0.62 and 0.82 within the age group less than 5 years (range with the highest predominance of correlation). Note that in 2000 $R^2 = 0.53$, in 2002 $R^2 = 0.68$, 2006 with $R^2 = 0.49$, 2007 stayed with $R^2 = 0.38$, 2013 $R^2 = 0.52$, 2014 and 2015 $R^2 = 0.41$. This suggests that these meteorological variables are well correlated with the disease (directly proportional). While in the other age groups there was a distribution of correlations in greater quantity classified as medium, null and weak.

This finding is in line with what was found in the study by Pontes *et al*., (2016) when they evaluated diseases of the respiratory system in relation to some climate variables (air temperature, rainfall and relative humidity) in the municipality of Ponta Grossa –PR. They found that in summer there is a lower rate of hospitalizations for pneumonia with a significant increase during autumn and its maximum peak being clearly observed in the winter months. This fact shows that during the period of low temperatures and high humidity, there is an increase in hospitalization rates, decreasing again in the spring, with the slow resumption of air temperature rise, reinforcing the results found in this research.

Table 3 - Correlation between cases of pneumonia and precipitation in Campina Grande

Years	<5 years old			Between 5 and 19 y. old			Between 20 and 59 y. old			Over 60 y.old		
	r	**R²**	**Classif.**	**r**	**R²**	**Classif.**	**r**	**R²**	**Classif.**	**r**	**R²**	**Classif.**
1998	0,17	0,03	Weak	0,45	0,20	Medium	0,58	0,34	Medium	0,75	0,57	Strong
1999	0,36	0,13	Medium	0,09	0,01	Weak	0,45	0,20	Medium	0,27	0,07	Weak
2000	0,73	0,53	Strong	0,56	0,32	Medium	0,74	0,55	Strong	-0,23	0,05	Weak
2001	0,21	0,04	Weak	-0,70	0,49	Strong	-0,67	0,45	Strong	-0,61	0,37	Strong
2002	0,82	0,68	Strong	-0,04	0,00	Null	-0,09	0,01	Weak	-0,17	0,03	Weak
2003	0,46	0,21	Medium	-0,27	0,07	Weak	-0,01	0,00	Null	0,09	0,01	Weak
2004	0,12	0,02	Weak	-0,63	0,40	Strong	-0,16	0,03	Weak	0,09	0,01	Weak
2005	-0,22	0,05	Weak	-0,42	0,17	Medium	0,05	0,00	Null	-0,11	0,01	Weak
2006	0,70	0,49	Strong	0,35	0,12	Medium	-0,06	0,00	Null	0,10	0,01	Weak
2007	0,62	0,38	Strong	0,09	0,01	Weak	0,13	0,02	Weak	0,77	0,60	Strong

Gestão & Regionalidade | São Caetano do Sul, SP | v.37 | n. 111 | p. 305-322 | maio-ago. | 2021 | ISSN 2176-5308

Years	<5 years old			Between 5 and 19 y. old			Between 20 and 59 y. old			Over 60 y.old		
2008	0,10	0,01	Weak	0,09	0,01	Weak	-0,40	0,16	Medium	-0,38	0,15	Medium
2009	0,39	0,15	Medium	-0,14	0,02	Weak	-0,46	0,21	Medium	-0,24	0,06	Weak
2010	0,42	0,18	Medium	-0,20	0,04	Weak	-0,52	0,27	Medium	-0,20	0,04	Weak
2011	0,58	0,33	Medium	-0,58	0,34	Medium	0,40	0,16	Medium	0,45	0,20	Medium
2012	0,15	0,02	Weak	-0,07	0,01	Weak	0,42	0,18	Medium	0,23	0,05	Weak
2013	0,72	0,52	Strong	-0,73	0,54	Strong	0,15	0,02	Weak	0,54	0,29	Medium
2014	0,64	0,41	Strong	-0,04	0,00	Null	0,22	0,05	Weak	0,07	0,00	Null
2015	0,64	0,41	Strong	-0,04	0,00	Null	0,22	0,05	Weak	0,07	0,00	Null
2016	0,48	0,23	Medium	0,26	0,07	Weak	0,25	0,06	Weak	-0,34	0,11	Medium

Source: Research data, 2017.

4.1 Correlation of cases of pneumonia with meteorological variables by age group in Campina Grande, PB.

Analyzing Table 4, it appears that it is from the month of May until the month of November that a discharge usually occurs in cases of hospitalization for respiratory diseases in the municipality of Campina Grande.

The cases of pneumonia present a greater amount in the months of May, June, July and August. It is possible to observe that in these months of greater precipitation, lower air temperatures and higher relative humidity occurred. These months refer to rainy periods in the city of Campina Grande, a period in which the humidity of the air tends to be very high, which in fact occurred in the city, thus contributing to the formation of molds, fungi and mites, in other words, vectors that increase the chances of increasing the number of people affected by respiratory diseases.

Table 4 - Monthly distribution of cases of pneumonia and meteorological variables

Months	Rainfall	Air temperature	Relative humidity:	Total cases of Pneumonia
Jan	1074,4	30,5	75,5	3788
Feb	1323,6	30,5	76,3	3122
Mar	1739,3	30,3	77,5	3667
Apr	1529,1	29,7	78,4	4363
May	**1959**	**28,1**	**81,3**	**5104**
Jun	**2589,8**	**26,3**	**83,7**	**5623**
Jul	**2197,4**	**25,7**	**83,4**	**5609**
Aug	**1427,5**	**26,8**	**80,5**	**4765**
Sep	636,3	28,2	76,0	4477
Oct	275,9	29,6	72,9	4543
Nov	193,4	30,6	71,8	4594
Dec	288,6	30,8	73,1	4119

Source: Research data, 2017.

The months with the lowest record of cases of pneumonia were January (3,788) February (3,122) and March (3,667) corresponding to the summer period. It appears that in the rainy period (May to August) 21,101 cases of pneumonia were registered, which corresponds to 39.24% of the cases.

Regarding climate variables, it is observed that the rainy season comprises the months of May, June, July and August in Campina Grande. Regarding the relative humidity of the air, the municipality has higher values in this period, which explains the increase in the number of hospitalizations. It is observed that the variables temperature and relative humidity present behaviors that follow the seasons, with higher temperatures in spring/summer and lower relative humidity in autumn/winter.

A justification for the values presented above is that, in the summer, the high temperature, together with a reduction in the relative humidity of the air, and the precipitation does not favor the increase in the number of notified cases of pneumonia in the municipality of Campina Grande. There is an increase in cases of the disease at the beginning of the rainy season, that is, as the temperature is decreasing and, the relative humidity of the air and the precipitation increasing, the number of cases registered of this disease begins to increase.

The high temperature, the low relative humidity of the air and the scarcity of rain, during the months of September to December, a period that corresponds to the spring, seem to contribute discreetly in the reduction of the number of cases during this season; however, a small increase in the incidence of the disease is observed at the beginning of this period.

Analyzing the hospitalization rates for pneumonia for the municipality of Campina Grande, monthly, there is a behavior that is repeated in the evaluated years, where the lowest hospitalization rates are perceived in the summer months, after which they rise during the autumn, its peak observed during the winter months, decreasing again during the spring. Again, the findings of this research are in line with the study by Pontes *et al*., (2016).

For general hospitalizations for pneumonia, the hospitalization rates of children under five years of age with this pathology had a similar distribution during the months of the year, with a lower rate of hospitalizations in the summer, with a significant increase during autumn and its maximum peak being clearly observed in the winter months. This fact shows that during the period of low temperatures and high humidity, there is an increase in hospitalization rates, decreasing again in the spring, with the slow resumption of air temperature rise, reinforcing the results found in this research.

The study shows that the average temperature and the relative humidity of the air have influenced the cases of pneumonia in the city of Campina Grande, during the analyzed period, reinforcing the thesis that sudden changes in temperature compromise the functioning of the eyelashes responsible for filtering the aspirated air, which leads to greater exposure to the microorganisms that cause the disease.

Mold (2008) points out that the reduction of the relative humidity of the air to values below 30% is considered a risk to the integrity of the airways, hindering the internal homeostasis of the respiratory system. In the rainy months, as opposed to the problems experienced in the dry months, the high relative humidity of the air, the crowding of people combined with the longer time spent indoors, the less ventilation and sun exposure of the home spaces, with consequent growth mold and fungi, are factors that can contribute to the increase in RD, especially allergic ones.

The results of the present study are similar and corroborate the study by Mendonça (2000), which demonstrated the relationship between temperature and respiratory diseases, observing in his study that when temperatures are low, there is an increase in the prevalence of diseases such as bronchitis, bronchiolitis, bronchitis chronic, asthma and pneumonia.

Murara *et al.,* (2013) also found similar results in their study, portraying statistical significance for the air temperature variable, which demonstrates that this meteorological variable influences the behavior of respiratory diseases in general and especially pneumonia.

Pearson's correlation coefficient at $p < 0.05$ between cases of pneumonia and the meteorological variables precipitation, air temperature and relative humidity are shown in Table 5.

Table 5 - Pearson's Correlation Coefficient (r) and Determination Coefficient in Campina Grande, PB - global monthly values

Meteorological Variables.	Pneumonia		
	r	R²	Classification
Rainfall	0,31	0,09	Average
Temperature	-0,71	0,51	Intense
Relative Humidity	0,47	0,22	Average

Source: Research data, 2017.

As the cases of pneumonia in the city of Campina Grande during the period under investigation are noted, a strong negative correlation between pneumonia ($r = -0.71$ and $R^2 = 0.51$), respectively, with air temperature, indicating that 69% of asthma cases had an inverse correlation with low air temperature values and 51% cases of pneumonia are influenced by air temperature, in other words, as air temperature decreases, there is an increase in cases of pneumonia, showing that care are needed when the temperature starts to drop.

The evidence found in this study reinforces the argument defended by Sette, Ribeiro and Silva (2012) when they analyzed the relationship of respiratory diseases in the urban area of Londrina/PR, Brazil and demonstrated the relationship between temperature and hospital admissions. It reinforces, in the specific case of the city of Campina Grande, PB, that the cases of pneumonia increase as the air temperature decreases.

Regarding the relative humidity variable, it is possible to observe that it presents an average positive correlation ($r = 0.47$ and $R^2 = 0.22$) for cases of pneumonia. These results indicate that, as the relative humidity increases, there is an increase in the number of pneumonia.

They found that in summer there is a lower rate of hospitalizations for pneumonia with a significant increase during autumn and its maximum peak being clearly observed in the winter months. This fact shows that during the period of low temperatures and high humidity, there is an increase in hospitalization rates, decreasing again in the spring, with the slow resumption of air temperature rise, reinforcing the results found in this research.

Regarding the precipitation variable, it showed a positive average correlation for pneumonia ($r = 0.31$ and $R^2 = 0.09$). The study shows that the average temperature and the relative humidity of the air have influenced the cases of pneumonia in the city of Campina Grande, during the analyzed period, reinforcing the thesis that sudden changes in temperature compromise the functioning of the eyelashes responsible for filtering the aspirated air, which leads to greater exposure to the microorganisms that cause the disease.

5 FINAL CONSIDERATIONS

The main contributions of the study point to a reality that is showing itself to be relevant within the context of public health management, especially with regard to the interference of climate variations and the supposed effects on the health of the population. In the specific case of the gap sought to be investigated, it can be inferred that:

- Notably, the respiratory diseases are very common and the ways of contracting them are also very comprehensive, so it is essential to carry out regionalized studies, in addition to identifying possible factors, such as climate change.
- The predominant age group for pneumonia was that of less than 5 years of age, followed by the age group of 60 years old or more, occurring in the municipality studied.
- The study shows that air temperature and relative humidity have influenced cases of pneumonia more frequently in the city of Campina Grande, PB, during the analyzed period.

The implications found point out that the higher the relative humidity of the air, and the lower the temperature of the air, the more cases of hospitalizations for pneumonia occur. They denote the importance of knowing the seasonality of certain diseases in order to allow health managers to take measures to prevent and promote the health of the population, especially when it comes to age groups with known characteristics and who can receive specific treatment, thus reducing the need for hospital interventions as advocated by Sette, Ribeiro and Silva (2012), Pontes *et al.* (2016), Mandú *et al.* (2019).

The limitation of the study focuses on the fact related to underreporting of diseases, lack of opportunity in registration, updating of data, incorrect diagnoses, among others, which may occur with the departments responsible for providing health information. This reality at any stage of the system leads to a problem in the dissemination of the analyzed information, thus making it difficult for society and health professionals to have the essential information for an adequate and efficient action.

Other respiratory diseases and meteorological elements could have been used in order to have a broader picture of the reality about the correlation between these variables and their impact on public health.

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