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The relationship of climate variables in the prevalence of acute respiratory infection in children under two years old in Rondonópolis-MT, Brazil

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Abstract *It is estimated that approximately 30% of childhood diseases can be attributed to environmental factors and 40% involve children under the age of five years old, representing about 10% of world population. This study aimed to analyze the relationship of climate variables in the prevalence of acute respiratory infection (ARI) in children under two years old, in Rondonopolis-MT, from 1999 to 2014. It was used a cross-sectional study with a quantitative and a descriptive approach with meteorological teaching and research data from the database from the health information system. For statistical analysis, it adjusted the negative binomial model belonging to the class of generalized linear models, adopting a significance level of 5%, based on the statistical platform R. The average number of cases of ARI decreases at approximately by 7.9% per degree centigrade increase above the average air temperature and decrease about 1.65% per 1% increase over the average air relative humidity. Already, the rainfall not associated with these cases. It is the interdisciplinary team refocus practical actions to assist in the control and reduction of ARI significant numbers in primary health care, related climate issues in children.*

Key words *Climate, Respiratory tract diseases, Child, Primary Health Care*

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Introduction

Health and environment issues must be the object of studies, seeking the understanding about the importance of understanding the behavior of how environmental factors interfere directly in the health-disease process. It is estimated that approximately 30% of childhood diseases can be attributed to environmental factors and 40% occur in children under the age of five years old, representing approximately 10% of the world's population. Children are particularly susceptible to environmental pollutants, due to distinct relationships with the environment and, therefore, forms and levels of exposure characteristic[1].

Climatic variations have direct impacts on public health and they are cited by various scholars since classical antiquity at the time of Hippocrates, in the book Airs, Waters and Places, about 400 C, linking health and human diseases to different atmospheric conditions[2]. It is important to note, however, that the source of the health problems associated with climate changes are multicausal and not necessarily results of climate changes[3].

The relationship between weather and climate with health is covered by human Biometeorology which consists in assessing the impact of atmospheric influences on man and is one of the biggest problems encountered, the identification of significant meteorotropics reactions in a givenpopulation[2]. The climate, among other factors, may raise the manifestation of certain diseases to health through their attributes (the temperature and air humidity, precipitation, atmospheric pressure and winds), which interfere with the well-being of the people[4].

The health system in the world will have to adapt to the answers that are occurring with climate change[5], as the increase in the incidence of extreme weather events, changes in rainfall patterns and air temperature that have unpredictable effects on damages. These changes may be related to an increase in respiratory diseases[6].

Acute respiratory infection (ARI) is the leading cause of disease in children under five years old, but there are major differences between countries regarding the gravity of mortality. Despite the higher prevalence of ARI in childhood, the low proportion of cases referred to a health service, observed in some countries, generate high incidence of severe cases and deaths[7].

A projection for 2030 performed by Mathers&Loncar, included fall in the number of respiratory infection mortality in the world and increase this rate for chronic respiratory diseases. However, respiratory diseases remain among the five main causes of mortality in high and low income countries. Regarding the deaths of under five years old, the forecast is 50% drop in the scenario between 2002 to 2030[8]. This interface between health and the environment, climatic variables temperature and relative humidity and precipitation should be studied and associated to healthreducing hospitalizations resulting from ARI in children, as well as complications and mortality by this cause.

Despite the shortage, some studies conducted in Brazil[1,9-14] understand the relationship of climatic variables with respiratory diseases. However, little has been studied about the influence of these variables on prevalence of ARI in children under two years old in primary health care. In the city of Rondonopolis-Mato Grosso, there are not known studies that link climatic variables and cases of ARI, justifying the development of this research and making necessary that this correlation be identified and studied extensively.

In view of the foregoing, the present research aimed to analyse the relationship between climatic variables in the prevalence of ARI in children under two years old in the city of Rondonopolis, in the period from 1999 to 2014.

Method

Area and study period

This research was conducted with data concerning the municipality of Rondonopolis, located in the State of Mato Grosso (MT), for the period January 1999 to December 2014. According to the Brazilian Institute of Geography and Statistics (IBGE 2010); Rondonopolis in 2013, had a population of 208,019 inhabitants with estimate for 2014 of 211,718. The area of territorial unit is equivalent to 4,159.118 km2 and population density of 47.00 in hab./km2, showing how the biome, the fenced-in land and tropical wet climate. Part of the microregion 538-Rondonopolis consisting of 19 municipalities with growth rate between 2013 and 2014 of approximately 1.8%, and ranks as the 8th most populous municipality in the Central-West region of Brazil. In MT, however, remains the third largest population[15].

The climate of Rondonopolis (MT) is characterized by an average annual temperature of 25°C, being the average of 32.6°C and the average of 18.6°C minimum. September and October are the hottest months with average temperatures above 26°C, June (21.9°C) and July (22.3°C) are those that feature the lowest averages[16]. The average annual rainning is between 1200 and 1800 mm and the rainy season focuses on spring and summer months (October to March). Already the dry season varies from 3 to 5 months. Usually in the afternoon, the indices of relative humidity fall enough, and may decrease the values extremely low[17]. In addition, as the relative humidity of the air in Rondonopolis, in the dry season, there is a gradual fall from May (71.0%) and June (66.9%), until it reaches the quarter with the lowest in July (62.4%), August (53, 4, 1%), September (57.5%) and October (68.3%). From November when the rainy season begins, the average values vary between 76.8 to 83.7%, and January is the month with the highest relative humidity[16].

Nature and data source

The survey used a cross-sectional study of quantitative and descriptive approach. The cross-sectional study or prevalence is one of the most used in epidemiological research designs, and may investigate cause and effect simultaneously and ascertain existing association between exposure and disease, viewing the situation of a population in a given time, as snapshots of reality[18].

Data collection in secondary sources, with all the data for the period under study, including only the ARI in children under two years old and the climatic variables: temperature, relative humidity and precipitation. It should be noted that the selection of this data series was due to the availability of sites found in official searches for this information and therefore, this period of sixteen years (1999-2014).

For this research, the series of data on weather variables were distributed in monthly averages obtained from meteorological database for education and research of the National Institute of Meteorology (INMET), concerning 83410 station-Rondonopolis-MT, latitude:-16,45, longitude:-54,56, altitude: 284,00m[19].

In relation to climate variables analyzed, the average monthly temperature of Rondonopolis fluctuated from 22.78°C in July to 26.82°C in October of 1999 to 2014. The year of 2003 showed the lowest annual average (23.79°C) and 2002 (25.72°C) the highest average. The average relative humidity ranged from 54.31% in August to 88.18% in January. The year 2005 presented the lowest annual average (71.53%) and 2014 (83.50%) the highest average. The average precipitation ranged from 3.6 mm month^{-1}; August to 285.2 mm/month^{-1} January. The year 2000 (511.45 mm year^{-1}) and 2006 (1527.7 mm year^{-1}) showed the lowest and highest proportion of rainning, respectively.

Data about the prevalence of ARI in children under two years old in Rondonopolis, were obtained from the database of the Department of Information of the Unified Health System (DATASUS) through the Health Information System for the basic attention (SISAB)[20]. According to the National Register of Health Establishments (CNESNET), this municipality has enabled 32 units of the Family Health Strategy, six Health Centers, a polyclinic and four Health Stations[21],which have an aspect ratio of population coverage of around 54, 57% of the current population. Making a comparison with the year of 1998, this proportion was 2, 34%, having deployed only one unit.

The cases of ARI in Rondonopoliswere distributed according to each month for the past sixteen years (1999 to 2014). There was registered a total of 83,465 cases, with an annual average of 5,216.56. June (8,631), July (8,983) and August (8,825) represent the months with a significant amount of cases. A monthly estimate in July of each year reveals an average of 561.44 cases/month and 18.71 cases/day. By contrast, the months of December and January showed, respectively, 5,262 and 5,305 cases of the disease, with the monthly averages of328.87^{-1} cases and 10.61 cases daily^{-1} and 331.56 cases monthly^{-1} and 10.69 cases daily^{-1}.

Ethical procedures

Because it is a survey with human beings and, even if the risk is minimal for being a study with information from database records, this project was submitted to the Research Ethics Committee of the Hospital Julius Muller and approved, being respected the ethical aspects of research with human beings (Resolution N 466/2012)[22].

Statistical analisys of data

To quantify the effects of meteorological variables (rainning, temperature and air humidity) exert on prevalence of ARI in under two years old children, there was adjusted the negative binomial model belonging to the class of generalized linear models (MLG), adopting a level of significance of 5% ($p < 0.05$). To assess the adequacy of the proposed statistical model to describe the observations, there were verified the normality and independence of errors. With this procedure, it sought theoretical conditions for performing the statistical analysis through univariable techniques.

The descriptive analysis of the data in terms of percentages of the dependent variables (prevalence of cases of ARI) and independent (meteorological variables), there was obtained by the measure of central tendency (average, median) and dispersion (standard deviation and percentiles) and the coefficient of variation (CV). Soon, the construction of the negative binomial regression model best suited to treat data with above-average conditional variance, there was drafted with the addition of a new parameter which reflects the heterogeneity not observed. The F-test was used to calculate estimates of the model parameters and their standard deviations, t test and the corresponding p-value for the dependent variable in relation to the significance of the independent variables.

To evaluate the fit of the model, an analysis of the waste through the normal probability graphics along with the Chi-square test to verify the suitability of the model fit to the data. Among the classes of models proposed by Box and Jenkins[23], ARIMA model was used to estimate cases of ARI. To select the best model among the models adjusted for the series, there were used the Akaike information Criterion (AIC)[24], Bayesian Information Criterion (BIC) and the Average Square Error of Prediction (NDE)[25]. Finally, the analyses were carried out with the aid of statistical platform R[26].

Results and discussion

As the data are countable, it might think, initially, in a Poisson model in which ARIi denotes number of acute respiratory infection cases in children under two years old, such that ARIi~ P (μi) where: $log\mu i$ = α + β1tempi + β2precipi + β3umidi.

For i = 1.2, ... 192. However, the adjustment of the model provided D (y;μ) = 21,614.00 to 189 degrees of freedom, indicating strong evidence about dispersion and there is significant evidence that the adjustment is not appropriate (p-value = 0.0001), which is confirmed by the normal probability chart of Figure 1. In addition, in Table 1, note that the fact of Poisson regression does not fit well to the data; it was also due to discrepancy that the variance will be compared to the average of the cases of ARI.

There is a negative binomial model in which *ARIi ~ BN (μi, ϕ)*. The normal probability chart, as well as the deviation D (*y*;μ) = 199.26, provide evidence of appropriate adjustments (*p-value* = 0.290). In addition, the Poisson distribution assumes that the events occur independently over time, that is, the probability of the child to be consulted and diagnosed with ARI in the health units in the municipality under study by the j^{-th} time is independent of $(j+1)^{-th}$ and $(j-1)^{-th}$ diagnosis.

From the clinical and practical points of view, this is a hypothesis that makes little sense, because once the child was consulted on primary health care, it is quite probably that it is not suggested another query to return in order to be verified the effectiveness of treatment proposed. Thus, the negative binomial distribution is best suited to handle the data whose variance is higher than the average probation, by adding new parameter which reflects the heterogeneity not observed. The results presented in Table 2 indicate that climatic variables: air temperature and relative humidity were significant to the 5% level of probability, with regard to the explanation of the rate of increase/decrease in the cases of ARI in Rondonopolis.

The coefficient $_1$= -0.082011 (Table 1) indicates reduction of the cases as a function of the temperature increase, that is, there is an inverse relationship between the variables under analysis. Therefore, it is expected that, for the months with the highest temperature records, the lowest rates of ARI cases are observed. Thus, exp (-0.082011) = 0.9212618, it is estimated that the average number of ARI cases decreases by approximately 7.9% with each degree centigrade increase in air temperature (Figure 2).

The coefficient related to relative air humidity, $_2$ = -0,0318, was negative, indicating a decrease in ARI cases due to the increase in humidity, ie, there is an inverse relationship between the variables under analysis. Thus, it is expected that, for the months with the highest humidity records, the lowest case indexes will be observed. That is, by taking exp (-0.016606) = 0.9835311, it is estimated that the average number of ARI cases decreases by about 1.65% for every 1% increase above the average relative air humidity (Figure 3).

The increase in the number of IRA is related to temperature and low relative humidity and there is statistically significant relationship with wind speed[27].

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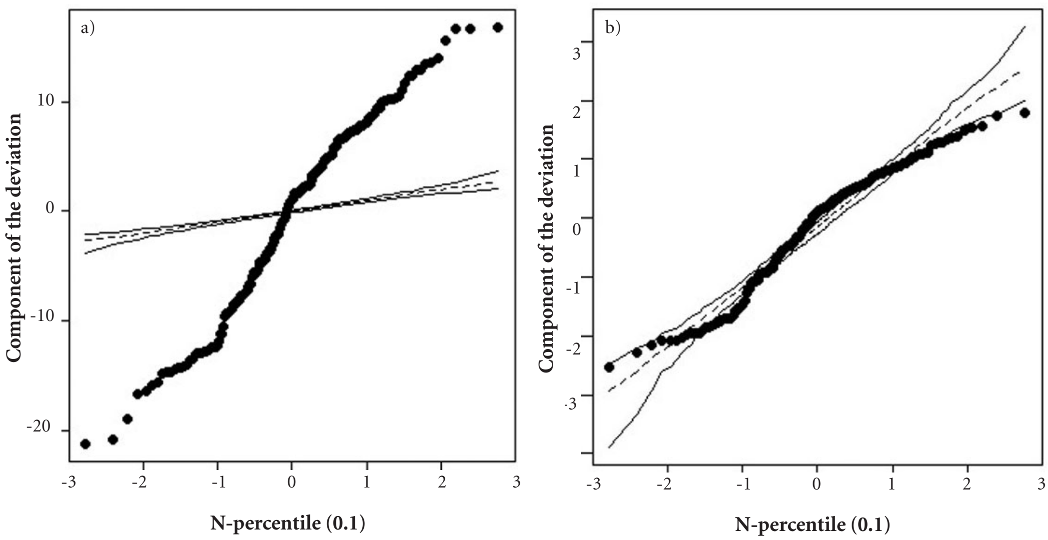

Figure 1. Normal probability charts refering to the log-linear models of Poisson (a) and binomial negative log-linear (b) adjusted to the data about prevalence of ARI in children under two years old, in the period from 1999 to 2014 in Rondonopolis-MT.

Table 1. Calculation of the average, variance, standard deviation and minimum and maximum values of the variables under study. Rondonópolis (MT), 2015.

Parameter	ARI (N of cases)	Precipitation (mm)	Temperature (°C)	Relative Humidity (%)
Minimum	103,0	0,0	21,0	42,0
Average	431,1	104,4	25,2	76,7
Variance	4.6510,4	1.1791,0	2,6	157,6
Standard deviation	215.7	108,6	1,6	12,5
Maximum	904.0	572,2	28,7	95,3

Table 2. Estimates of the model parameters and their standard deviations, t test and the corresponding p-value for occurrence of acute respiratory infection (ARI), during the period from 1999 to 2014 in Rondonopolis.

Coefficients	Estimate	Standard error	T test	p-value
Intercept ($\hat{\beta}_0$)	9,371591	0,559763	16,742	< 0,001
Average temperature of air ($\hat{\beta}_1$)	-0,082011	0,021540	-3,807	< 0,001
Relative humidity ($\hat{\beta}_2$)	-0,016606	0,002771	-5,993	< 0,001

Given the exposed, it considers that July and August were the months that these years of analysis showed the largest amount of ARI cases in Rondonopolis, coinciding with the months provided the lowest average air temperature and relative humidity in these periods should be intensified interdisciplinary actions for the control of these occurrences of ARI in children under two years old.

Corroborating the results of this survey, some authors have demonstrated the relationship of climate variables with occurrence of ARI in some localities: the ambulatory care for respiratory diseases in children under five years old in the

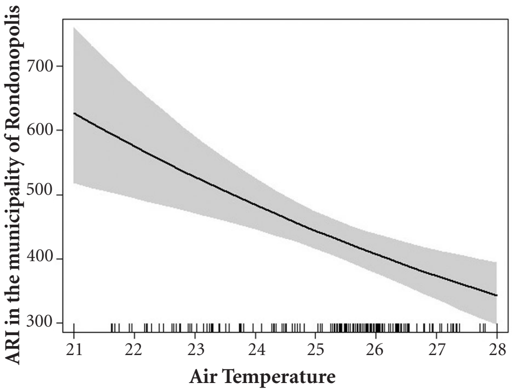

Figure 2. Conduct of cases of acute respiratory infection (ARI) in children under two years old, in relation to air temperature in Rondonopolis, 1999 to 2014.

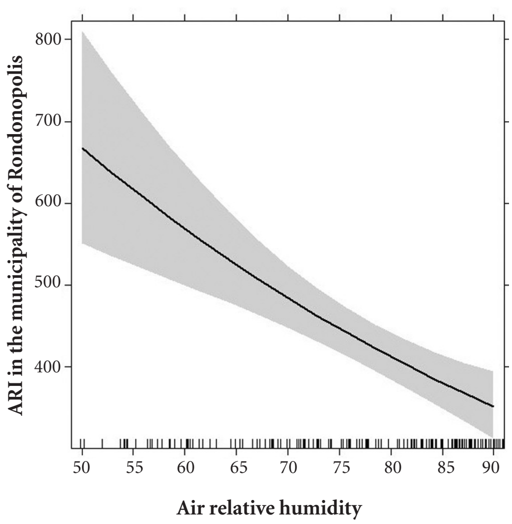

Figure 3. Conduct of cases of acute respiratory infection (ARI) in children under two years old in relation to the relative humidity in Rondonopolis, 1999 to 2014.

city of Alta Floresta (MT) had seasonal peaks in the dry season, 56% of cases, while in rainy, 44%[28]; in Campo Grande (State of MatoGrosso do Sul) showed inversely proportional relationship between respiratory diseases in children and climatic indicators (temperature, humidity, human thermal comfort indices and precipitation)[29]; in a basic health unit in Goiania (Goias) the temperature variation was not enough to cause changes in the number of children with respiratory symptoms; however, there was an increase with low levels of moisture and precipitation in winter[30].

In the case of ARI in children from a daycare center in São Jose do Rio Preto (São Paulo), the rhinovirus was detected in autumn and lower in the summer[11]. The seasonality of respiratory syncytial virus (RSV) in a hospital of São Paulo, indicated high incidence in winter[10]. There was moderate correlation between hospitalizations for respiratory diseases (RDs) in Florianopolis with temperature[13]. In the city of Cuiaba the ARI care in children under five have been frequent during the rainy season; however, the dry season influenced hospitalization rate in severe cases of the lower tract, due to high temperature, low humidity and greater number of hotspots[9]. In Campina Grande (State of Paraiba), there was association of reducing the temperature and humidity increase, with a higher incidence of respiratory diseases in children under two years old[14].

In Curitiba, respiratory diseases in children are influenced by temperature in an inverse relationship[31]. In Patrocinio (Minas Gerais) drop in temperature contributed to increased respiratory problems in dry months with low humidity[32]. In general, respiratory infections increase during the winter and will vary depending on the degree to which the temperature rises in relation to current levels[33]. ARI in children in São Jose do Rio Preto (São Paulo) showed inverse association with humidity and temperature[34]. In Fortaleza respiratory virus circulation is seasonal and there was relation of cases of ARI with humidity and precipitation[35].

In the South of the country, the peak of RSV in children under two years old focused in winter, coinciding with the influenza season[36]. The transmission of RSV was higher in regions with high temperature and humidity[37]. Outbreaks of ARI in children under five, hospitalized in the city of Uberlandia occurred during low temperature and humidity[38]. The increased risk of hospitalization of children was noted in Campo Grande, in winter and decrease of pneumonia in the warmer months[39].

Some international studies show that in children, the incidence of respiratory infection is attributed to climatic parameters, mainly temperature and precipitation[40]; temperature is associated with pneumonia, sinusitis and asthma and humidity to asthma and tonsillitis[41]; in the United States, temperature and precipitation were associated with RSV in children under five years old in winter[42]. The RSV in children under three occurs only a few cases in the summer in Utah[43].

The ARI in outpatient consultations was greater in children in nine States in the US and the RSV was detected in the summer and influenza in winter[44]. In Colorado, ARI predominated from November to May[45]. In Guangzhou (China), temperature was associated with respiratory infections in children from zero to two years old, and the increase in the number of outpatient consultations occurred in cold temperatures[46]. In children under five met in Shanghai (China), had in winter peak[47].

The cases of ARI households of under five years old children showed a relationship with rainfall in Dhaka (Bangladesh), in periods of intermittent rain, characterized with high temperature and humidity, and was raised a chance that children remain longer in crowded and closed environments, increasing the exposure to other people and risk to illness[48]. Influenza in Africa is related to outpatients and there is a moderate amount of cases in winter[49].

In Acharnes (Greece), respiratory infections in ambulatory consultations were associated with low temperature and humidity in cold[50]. The rhinovirus appears in early fall; the RSV in December and January, and influenza in the fall-winter[51]. The seasonality of the RSV of children in clinics and hospitals in the Philippines is associated with precipitation; humidity and temperature did not show relations[52]. In Australia, under two years old children with RSV in out-patient and hospitalization, there were peaks in winter and a few in the summer[53].

In contrast with the results found in this research in Tangara da Serra (MatoGrosso), the care for respiratory diseases in basic units occurred mostly in the age group from zero to four years old (52%) and on average 21% less frequent in the dry period; the lowest humidity and air temperature contributed to the reduction of these services[54]. In the same municipality, the climatic seasonality was also considered as a risk factor for hospitalization for respiratory diseases; in the dry season, 10% more hospitalizations occurredthan in the rain season, in addition to relative humidity and rain intensity interfere with rates of hospitalizations[55]. Analyzing the stations in the metropolitan region of São Paulo, in the months of April and May, there is a tendency of increased air temperature; thus, increasing morbidity of respiratory diseases, most commonly in children and the elderly, given the positive correlation coefficients, comparing to diseases of upper airways and the monthly minimum temperature[2].

In relation to the rain precipitation there was no relationship with ARI in Rondonopolis. However in Ceara, in children, there was greater incidence in rainy periods, when historically outbreaks occur[56]. The RSV coincides with the rainy season in a series of tropical locations. In outpatient health care services, in the city of Maceio, the increase of the RSV had weak correlation with temperature and moderate rain. In Curitiba there was correlation between temperature and precipitation decrease and increase of influenza[57]. In Fortaleza, RSV in children under two years old served as an outpatient and in hospitals; it was higher in the rainy season and most of the cases were diagnosed in the Pediatric outpatient[58]. Children up to nine years old, in Manaus, had higher rates of hospitalization for respiratory diseases during the rainy season[12]. The prevalence and seasonal distribution of pathogens in children under five years old with ARI in clinics, in Recife (Pernambuco), they were of the ARI during the rain[59].

One of the limitations of this study is the absence of data about the race of those children from the city under study. The ARI for RSV indigenous and non-indigenous children under five years old in Perth (Western Australia), had a distinct seasonality in most geographical areas with peaks in winter associated with cold temperatures and increased rain seazonality. Already the ARI for influenza had peaked in winter, but there'sbeen a pattern with the indigenous peak in fall and spring[60]. Similar results, in Kalgoorlie-Boulder (Western Australia), in the indigenous the rhinovirus type A was more detected during winter and the type C showed no seasonal variation. Already in non-indigenous, there was no seasonal variation in detection of any type of rhinovirus[61].

In the absence of data from Rondonopolis, about exact age and gender of children with ARI, it would be important that these data were detailed, since these variables can influence the occurrence of ARI. On viral etiology of ARI in under five years old children hospitalized in Uberlandia (Minas Gerais) the RSV presented significant difference in age, mainly, with large numbers in under three months old; already the parainfluenza and rhinovirus showed no differences between ages[38].

This research it is children under two years old and they might already attend educational institutions such as nurseries, kindergartens and schools. It is valid to note that the seasonal variability can be connected to the contact rates among children related to school semesters; for example when children return to school from vacation, and this factor could lead to seasonal influenza[62].

It should be noted that, in the case of secondary data which may present problems relating to their registration, coverage and quality; one should be cautious when interpreting the findings of the present study. It is possible that limitations, such as the sub-register and incomplete data fulfilment by the units may have affected the results. It is important to also consider that it is possible that the vacations of the team professionals, highlighting the of doctors and nurses, may influence in a reduction of the number of attendances to children. In addition, the data of children are absolute, not showing age, gender, location and type of housing in the municipality, race and other information that could interfere with the prevalence of respiratory diseases, such as the detection of the pathogen, the susceptibility of the host and the social networks that these children attend. In such a way that it has not been possible to contemplate the urban differences, being presumed that the trends presented here are not occurring identically in all areas of the municipality.

Another important topic would be the city data providing information about the type of pathogen that causes ARI, in addition to the symptoms presented and that it could be possible for a diagnosis about the severity and need to hospitalization. The RSV types A and B in children served at the Clinic Hospital of Uberlandia (Minas Gerais) demonstrated no statistical differences as the clinical severity of the disease, but in general, there were detected between January and June[63].

Fits warn that one of the limitations of this study includes the coverage factor of public health service of the population of Rondonopolis by the units of primary health care, through the FHS, generating a restriction inherent in the system itself, since part of the ARIs are answered at offices for private health inssurance, such ascovenants or private and the data are not registered and are not available.

This way, the generalization of the results should be made for populations that present similar characteristics of those met in the FHS of SUS and living in areas where climatic variables resemble found in the region of Rondonopolis-MT.

Final notes

The relationship between health and climate variability must be worked by primary health care, seeking relations interaction of individuals with environmental conditions, especially those that can cause disease. Professionals should propose actions associated with the climatic environmental risk factors present in the context of action[64]. In addition, they must be carried out by professionals of a multidisciplinary team and integrated, whereas the Single Health System (SUS) as articulating axis of care to full needs, through promotion, prevention and recovery of health. It requires a defragmented and plural look of the various professionals, in order that there be implemented health actions turned to this problem. Such interventions should be more effective in the field of promotion and protection of health and the prevention of climatic environmental risks to the health of the population, in particular children.

Climatic variables: temperature and relative humidity are inversely related to the cases of acute respiratory infection (ARI) in Rondonopolis-MT, so that there is a need for a reformulation of the actions of promotion of health and prevention of this disease in children in the primary health care units, during the years with low values of these variables by decreasing the rates of hospital admissions and deaths by these diseases.It is due to the interdisciplinary team a full performance, establishing as a priority, the relevance of these climatic factors as influencers in the cases of ARI, considering the other factors that interfere with the occurrence of this disease.

It is expected that this research will contribute significantly to further investigation in these areas, in order to stimulate debates that start the discussion on the interfaces of this issue and extend the knowledge of professionals, aware the population, in addition to reorient and encourage practical actions to aid in the control and reduction of significant numbers of ARI in children under two years old on primary health care related to climate issues.

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Collaborations

DAS Santos and PV Azevedo participated in the design of the project and of all stages of the article, R Olinda worked on the design and data interpretation, CAC Santos, A Souza, DM Sette and PM Souza worked on analysis, review and article writing.

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