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METEOROLOGICAL VARIABLES AND THE NUMBER OF HOSPITALIZATIONS FOR ACUTE MYOCARDIAL INFARCTION IN BELÉM/PA

Ana Vitória Padilha Mendes¹; Arthur Wendell Duarte Silva²; Ana Carla dos Santos Gomes³ Lucas Vaz Peres⁴ Antonio Marcos Delfino de Andrade⁵

¹University graduate, IEG/Atmospheric sciences, Universidade Federal do Oeste do Pará (UFOPA), Santarém/PA, Brasil.

ORCID: <https://orcid.org/0000-0002-0569-4297>

E-mail: nha_2309@hotmail.com

²University graduate, IEG/Atmospheric sciences, Universidade Federal do Oeste do Pará (UFOPA), Santarém/PA, Brasil.

ORCID: <https://orcid.org/0000-0002-1746-3832>

E-mail: arthurweendell@gmail.com

³Doctor teacher, IEG/Atmospheric sciences, Universidade Federal do Oeste do Pará (UFOPA), Santarém/PA, Brasil.

ORCID: <https://orcid.org/0000-0001-7499-8342>

E-mail: anacarlasg02@gmail.com

⁴Doctor teacher, IEG/Atmospheric sciences, Universidade Federal do Oeste do Pará (UFOPA), Santarém/PA, Brasil.

ORCID: <https://orcid.org/0000-0002-5612-5991>

E-mail: lucasvazperes@gmail.com

⁵Doctor teacher, IEG/Atmospheric sciences, Universidade Federal do Oeste do Pará (UFOPA), Santarém/PA, Brasil.

ORCID: <https://orcid.org/0000-0002-2075-7890>

E-mail: marcoslaba33@gmail.com

Abstract

The objective of this study was to verify whether the meteorological variables significantly influence the causes of morbidity due to acute myocardial infarction in Belém do Pará. For this purpose, maximum and minimum air temperature, relative humidity, rainfall and velocity data were used. of the wind, made available by the Meteorological Database for Study and Research of the National Institute of Meteorology and hospitalization data for AMI obtained through the Department of

Informatics of the Unified Health System, both in the period from 2008 to 2018, totaling 10 years of data, 4242 admissions were recorded during this period. Descriptive statistics and modeling using Generalized Estimation Equations were used to verify association, using the free software R 3.4.1. Finally, the results indicate a significant association between maximum air temperature, wind speed and the number of hospitalizations. The synergy between the increase in maximum temperature and decrease in wind speed favored the increase in the number of hospitalizations in Belém, it is believed that the results observed may be a good contributor to public health policies.

Keywords: Statistical modeling; Morbidity; Climate.

VARIÁVEIS METEOROLÓGICAS E O NÚMERO DE INTERNAÇÕES POR INFARTO AGUDO DO MIOCÁRDIO EM BELÉM/PA

Resumo

O objetivo deste estudo foi verificar se as variáveis meteorológicas influenciam de forma significativa nas causas de morbidade por Infarto agudo do miocárdio em Belém do Pará. Para isso foram utilizados dados de temperatura máxima e mínima do ar, umidade relativa do ar, precipitação pluvial e velocidade do vento, disponibilizados pelo Banco de Dados Meteorológicos para Estudo e Pesquisa do Instituto Nacional de Meteorologia e dados de internações por IAM obtidos através do Departamento de Informática do Sistema Único de Saúde, ambos no período de 2008 a 2018, totalizando 10 anos de dados, foram registradas 4242 internações durante esse período. Utilizou-se a estatística descritiva e a modelagem via Equações de Estimação Generalizadas para verificar associação, por meio do *software* livre R 3.4.1. Por fim, os resultados assinalam associação significativa entre a temperatura máxima do ar, velocidade do vento e o número de internações. A sinergia entre o aumento da temperatura máxima e diminuição na velocidade do vento favoreceram para o aumento do número de internações em Belém, acredita-se que os resultados observados possam ser um bom contribuinte para políticas públicas de saúde.

Palavras-chave: Modelagem estatística; Morbidade; Clima.

VARIABLES METEOROLÓGICAS Y EL NÚMERO DE HOSPITALIZACIONES POR INFARTO AGUDO DE MIOCARDIO EN BELÉM/PA.

Resumen

El objetivo de este estudio fue verificar si las variables meteorológicas influyen significativamente en las causas de morbilidad por infarto agudo de miocardio en Belém do Pará, para lo cual se utilizaron datos de temperatura máxima y mínima del aire, humedad relativa, precipitación y velocidad. el viento, puesto a disposición por la Base de Datos Meteorológicos de Estudio e Investigación del Instituto Nacional de Meteorología y datos de hospitalización por IAM obtenidos a través del Departamento de Informática del Sistema Único de Salud, ambos en el período de 2008 a 2018, totalizando 10 años de datos, Se registraron 4242 admisiones durante este período. Para verificar la asociación se utilizó estadística descriptiva y modelado mediante Ecuaciones de Estimación Generalizadas, utilizando el software libre R 3.4.1. Finalmente, los resultados indican una asociación significativa entre la temperatura máxima del aire, la velocidad del viento y el número de hospitalizaciones. La sinergia entre el aumento de la temperatura máxima y la disminución de la velocidad del viento favoreció el aumento del número de hospitalizaciones en Belém, se cree que los resultados observados pueden ser un buen contribuyente a las políticas de salud pública.

Palabras-clave: Modelado estadístico; Morbilidad; Clima.

1. INTRODUCTION

Cardiovascular diseases can affect the heart and blood vessels, highlighting coronary artery disease, which involves chest pain, and acute myocardial infarction, which is the largest cause of morbidity and mortality in the world. In Brazil, according to the Ministry of Health, about 300 thousand individuals per year suffer Acute Myocardial Infarction (AMI), with death occurring in 30% of these cases (BRAZIL, 2019). In Brazil, AMI results in high mortality incidence rates, reaching around (183,3/ 100,000 inhabitants) being among the highest in the world and is similar to that of countries such as China and areas such as Eastern Europe (SANTOS et al, 2018).

As reported by the Ministry of Health, myocardial infarction, or heart attack, is the death of cells in a region of the heart muscle due to the formation of a clot that disrupts blood flow suddenly and intensively (WO, 2018). The main cause of the infarction is atherosclerosis, a disease in which fatty plaques accumulate inside the coronary arteries, eventually clogging them. In these cases, the infarction occurs when one of these plaques ruptures, leading to clot formation and interruption of blood flow, conforming to Bacelar, 2012.

In agreement with Medeiros (2018), healthy eating since childhood is essential for health and decreases the risks of Cardiovascular Diseases in the future. The eating habits of youngest people have changed significantly in recent decades due to the large consumption of foods high in fat, cholesterol, and carbohydrate. Consequently, these people tend to have a higher risk of acquiring CVD in adulthood.

Unsurprisingly, climate change has direct and indirect effects on health, however, there has never been so much attention given

to research involving the issues related to environmental variables and human health. Evidence of this is the various studies carried out worldwide by the most diverse professional researchers, both from the exact sciences and biology, forming a union between these areas, increasing the level of research with interdisciplinary, which aims at a better understanding of the interrelations between living beings and the environment. In consonance with Pereira et al., 2012, the changes that occur with meteorological variables over some regions are targeted as a very worrying factor by climatology scholars and it is known that these changes do not only influence the microclimate of these regions, they can cause considerable physiological variations with regard to diseases related to climatological variables.

The study of the relations between the Biosphere and the atmosphere nowadays has become a science whose purpose is to prevent people at risk, due to the great influence of the meteorological elements on the human organism (PEREIRA, 2012). Therefore, the effects of climate change can also affect directly or indirectly, generating physical, traumatic, psychological, infectious, and nutritional consequences (OLIVEIRA, 2019). In line with (DILAVÉRIS, et al, 2006), the contribution of climatic conditions to this end has been recognized in several studies that indicate a seasonal variation in morbidity and mortality rates of cardiovascular disease.

Climate change affects alterations arising from changes in air temperature, precipitation, among other phenomena, in relation to historical averages, so that they end up interfering with the climatic characteristics of the planet (ARAÚJO, 2018). For Lee et al., 2010, in recent years, much attention has been paid to the seasonal variation of AMI. Different warnings indicate that Acute Myocardial Infarction most commonly occurs in cold seasons, especially in temperate and cold zones. Hence, some reports from subtropical areas have revealed that hospital admissions for AMI rise during the hot summer seasons compared to the winter seasons (IKEFUTI, 2017). In this way, Acute Myocardial Infarction is similar to thermal stress, that is, where temperatures reach extremely cold or hot spots. In keeping with Goerre et al., 2007, the first investigations of the interactions between climate and the incidence of Acute Myocardial Infarction are since 1938.

For Morabito et al., 2005, the combination of air temperature, relative humidity, and wind speed provides apparent temperature values that allow an assessment of the increased perception of human discomfort caused by the compromised efficiency of enhanced transpiration. However, the effect of warm weather conditions may not be appreciated by considering only average daily air temperatures (MORABITO et al. 2005). Studies conducted in tropical regions have also reported that hot weather can increase the incidence of acute infarction (MORABITO et al. 2005).

In the work done by Teng and Heyer., 1955, it was found that there is a significant association between maximum temperature and the number of cases per AMI in the city of Dallas, located in the tropics, in the north of the state of Texas/USA. It was revealed that when the seasonal occurrence was tabulated, the highest number of cases occurred during the summer months and the lowest number of cases during the winter. The occurrences are linked to the tropical air intake, carried by south or southeast winds, causing an increase in air temperature and a simultaneous reduction in barometric pressure.

Also as claimed by Teng and Heyer., 1955, there were cases where patients had the onset of AMI symptoms inside their homes, in a warm environment, during sleep, or at rest. According to Heyer and Teng (1953), in a climate characterized by a lot of heat (summer climate), AMI occurs more often during the hottest season of the year. Besides influencing the microclimate of regions, they can cause considerable physiological variations with regard to diseases related to meteorological variables, thus aggravating some pre-existing diseases and favoring the onset of others, thus becoming a public health problem (PEREIRA *et al.*, 2007). In light of the foregoing, the objective of this study is to verify whether the meteorological variables significantly influence the causes of morbidity by Acute Myocardial Infarction in Belém/PA.

2. METHODOLOGY

The study site was the municipality of Belém, capital of the state of Pará (01°27'20" S; 40°30'15" W), which has a territorial area of 1,059.458 km² (Figure 1), located in the equatorial zone, on the shores of Guajará Bay and Guamá River, 120 km away from the Atlantic Ocean (IBGE, 2018). As maintained by the Koppen-Geiger classification, Belém has a tropical climate of the Am. type, with an average annual precipitation of 2537 mm. As a region where rainfall is constant, the city has two seasons: the rainy season (December to May) and the less rainy season (June to November), as described by Nechet (1984), Figueroa and Nobre (1990), Bastos *et al.*, (2002) and Oliveira *et al.*, (2003).

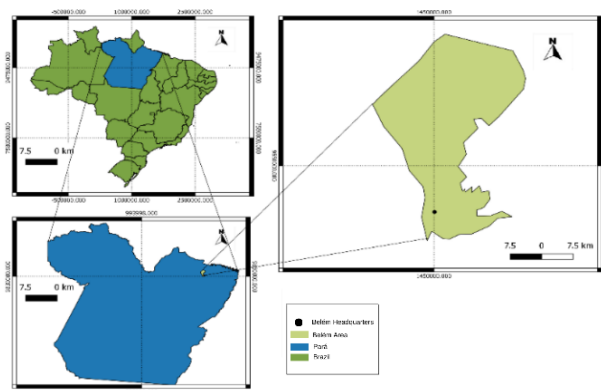


Figure 1 - Geographical location of the study area. Source: IBGE (2019), adapted by the authors.

For this study, we used monthly data of meteorological variables rainfall (mm), maximum and minimum air temperature (°C), relative humidity (%) and wind speed (m/s) from the weather station (-1.43° S; -48.43° W; 10.00 m alt.), available from the National Institute of Meteorology (INMET).

A total of 4182 cases of morbidity due to AMI were recorded from 2008 to 2018 by the Department of Informatics of the Unified Health System (DATASUS). Since the SUS was implemented, DATASUS has the main objective of structuring health information systems, aggregating health data, as well as facilitating the management of the various levels of health care (DATASUS, 2019).

With the monthly series data, the annual totals of the variables were obtained. Climatology is represented by graphs of the type *Boxplot*. O *boxplot* it allows you to summarize the data and thus show the median that is represented by Q2 or second quartile, located within the box and point values represented by Q3 (third quartile) that totals 75% of the maximum values and the minimum Q1 (first quartile) representing 25% of these values. The rod (*mustache* or *whisker*), represents the values located between the *box* and the limit values, defined by Tukey's norms (Wilks, 2006), following the following expressions:

$$x1 = Q1 - 1,5 * 1QR \quad (1)$$

$$Xn = Q3 + 1,5 * 1QR \quad (2)$$

Where, " IQR " represents the interquartile range (Q1-Q3) and the points outside these limits are considered discrepant values (outliers).

The modeling via Generalized Estimation Equations (GEE), proposed by Liang and Zeger (1986), aims to estimate regression parameters when the data are correlated. On many occasions, although the variables studied are independent, information about a particular variable is collected several times over time, becoming correlated observations (GOMES, 2015).

Liang and Zeger (1986) developed the GEE using quasi-likelihood models (WENDDERBUN, 1974) to analyze longitudinal data and requires only the specification of the relationship between mean and variance of observations (AGRANONIK, 2009). However, a generalized linear model is defined for each point in time, adding a function that links the random part to the systematic part:

$$nit = g(\mu it) \quad (3)$$

The linear predictor is the vector of unknown and interesting parameters and is the link function. The structure for the correlation matrix of the symmetric or interchangeable type is used. The techniques used were applied with the help of statistical software R 3.5.3. The *geepack* (Generalized Estimating Equation Package) and the *geeglm* (Fit Generalized Estimating Equations) function were used for modeling via generalized estimating equations.

The definition of relative risk (RR) is given by the ratio between the probabilities of success of two levels of the explanatory variable (AGRESTI, 1996), and the Relative Risk equation is given by:

$$RR = \frac{\pi 1}{\pi 2} \quad (4)$$

We used the structure for the correlation matrix of the symmetric or interchangeable type, which assumes:

$$R(\alpha) = \{1 \text{ se } t = t'. \alpha \text{ se } t \neq t'. \quad (5)$$

Equation 5 should be used when you have a random effects model with a random intercept for each of the variables, as exemplified in Laird and Ware (1982).

To fill in the gaps (2 months in 2015), we used the multiple imputation method via MICE (*Multivariate Imputation by Chained Equation*), whose The Same is based on the Monte Carlo method via Markov chain (LI *et al.*, 2017). MICE is available with a package entitled 'mice'.

3. RESULTS AND DISCUSSION

The time series of the number of cases due to Acute Myocardial Infarction hospitalizations represented by Figure 2 emphasizes three periods of increase in the number of cases for the first period from 2012 to 2013, the second from 2014 to 2015 and the third from 2016 to 2018, where a significant growth is observed, with an even greater magnitude for the years 2016 and 2018. And a period of fluctuation in the number of cases around an average value ranging from 2008 to 2010. Until 2012, the number of annual hospitalizations was less than 350 cases. And from 2014 a probable growth trend was observed, which presents values exceeding 600 cases.

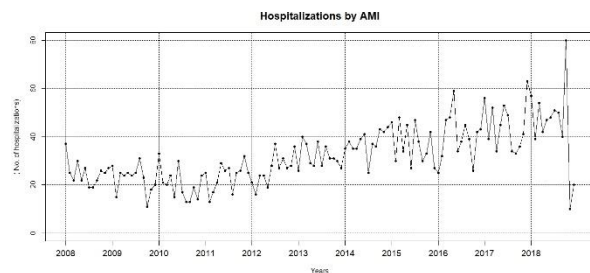


Figure 2 - Time series of the number of cases per hospitalization for Acute Myocardial Infarction in the years 2008 to 2018 for the study region. Source: author (2021).

Studies have already proven that the occurrence of cardiovascular diseases is listed with obesity, changes in blood pressure, as well as lifestyle habits such as smoking, alcohol intake and increased thermal discomfort (MANDÚ *et al.*, 2019). Recent literature indicates understanding the increase in thermal conditions as one of the risk factors, and also stimulates the work in tropical and subtropical regions (PHUNG *et al.*, 2016).

Figure 3 shows the variability of hospitalizations for AMI during the analyzed period, highlighting the month of March, which presented the greatest variation in the number of hospitalizations, with values above 45 cases. It is also observed that throughout the year, only in the month of October there is a lower outlier, a discrepant value in the series, where in the same month it was found that the lowest number of cases was below 35 hospitalizations. The month of October also has a higher outline, which indicates, therefore, that in one of the years of the studied

period there was a relevant number of hospitalizations, as well as the month of December.

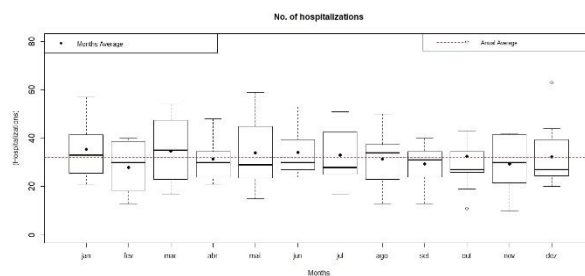


Figure 3 - Boxplot of the number of monthly hospitalizations for AMI in Belém-PA in the period from 2008 to 2018. Source: authors (2021).

By analyzing the behavior of the time series of minimum and maximum air temperatures in Belém do Pará in the studied period (Figure 4 and 5), it was found that the minimum temperature presented lower values in the years 2013 and 2015, where the values are below 23.0 °C and higher in the years 2011 and 2016 with values above 24.0 °C.

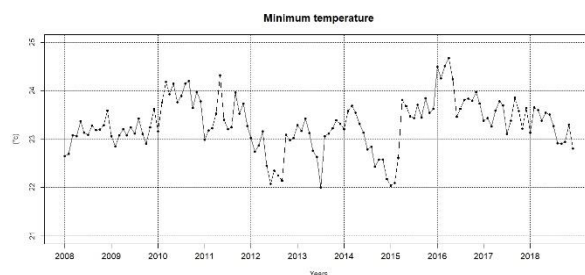


Figure 4 - Time series of the minimum air temperature in the years 2008 to 2018, for the study region. Source: author.

The time series of maximum temperature (figure 5) in Belém presents values above 29.0 °C during the entire period analyzed. Values below 30.0 °C were recorded in 2008. The years 2015 and 2016 stand out, periods with records above 34.0 °C.

In the case of these temperatures being higher, it is characterized by Belém being graphically located close to the equator, due to its low local altitude, and the small thermal exchange being related to the rainfall regime in the region, due to the maximum temperatures being less frequently emphasized and occurring during the rainiest period, while the highest attend with the least rainy period (BASTOS, 2002).

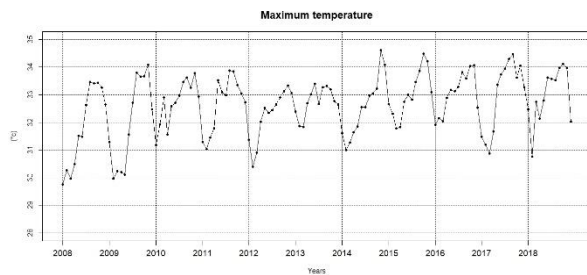


Figure 5 - Time series of the maximum air temperature in the years 2008 to 2018, for study region. Source: authors (2021).

Figure 6 shows the graph that shows the monthly variability of the minimum air temperature, and it is possible to note that this seasonal variability has a dominant semi-annual cycle, with two minimum average values, January (23.13°C) and July (23.08°C), and two maximum average values in the months of May (23.41°C) and April (23.8°C). It is possible to observe the presence of several discrepant values, both lower and higher.

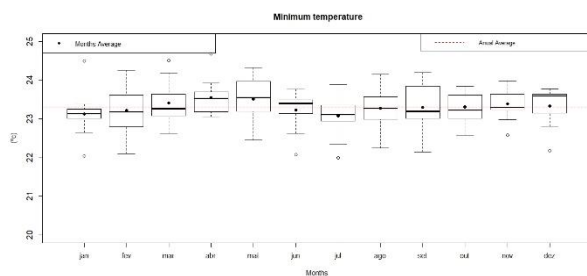


Figure 6 - Monthly Boxplot of the minimum air temperature from 2008 to 2018, in Belém do Pará. Source: authors (2021).

It is observed that in Bethlehem temperatures are always high, and this is associated with 15careful15 incident solar radiation potential, although much of this energy is converted into heat 15and other part converted into sensitive heat that is attributed to heating the air, (NECHET ,1984).

It is possible to observe that the maximum monthly temperature (figure7) demonstrates the well-defined annual cycle, with the lowest average value in February (31.17 °C) and the highest in November (33.74 °C). It also presents discrepant values in April, July and December and lower outlines in the months of January, March and May.

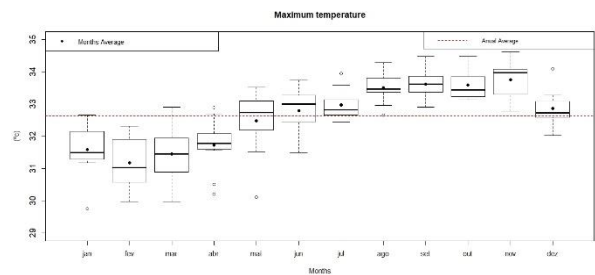


Figure 7 - Monthly boxplot of maximum air temperature from 2008 to 2018 in Belém, Pará. Source: author.

Figure 8 shows the annual precipitation series and it is notorious that the years of 2008, 2011 and 2012 were under the influence of the La Niña phenomenon that increased the rainfall in the city of Belém (Oliveira et al.,2016). The years 2010 and 2015 show lower values, which were influenced by the El Niño phenomenon that causes the reduction of rainfall indices in the Amazon region, the “famous afternoon rain” in Belém, has a great contribution to the monthly totals, being the 4 pm the time of greatest contribution, in the period between dawn and early morning, the contribution values are minimal (MORAES, 2017).

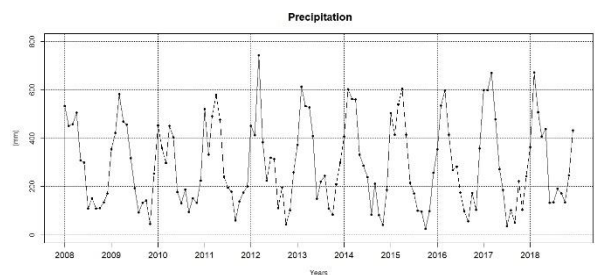


Figure 8 - Time series of accumulated precipitation (mm) in the years 2008 to 2018, for the study region. Source: authors (2021).

Between the years 2008 to 2018, there is greater variability of rainfall in the months of January, March, June and August (Figure 9). The period of highest rainfall occurred from January to May, with emphasis on March having its maximum value of 543.5 mm and with greater drought from July to November, with lower value in the month of September, totaling 118 mm.

According to Vianello; Alves (2013) within the local circumstances, it can be described that the precipitation in Belém/PA as resulting from the following situations: from December to May, the rainy season, the precipitation is originated by the Intertropical Convergence Zone (ICZM), and by mesoscale effects, such as the lines of instabilities that form on the Atlantic coast of Guianas and Pará, and propagate to the west as a line of cumulonimbus (BASTOS et al., 2002, p.14).

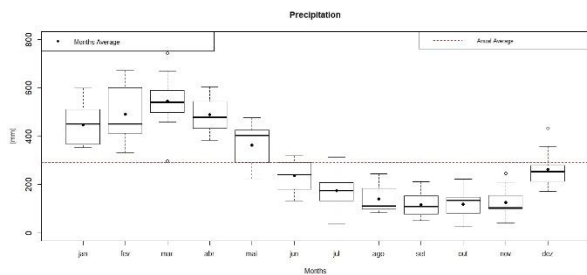


Figure 9 - Boxplot of rainfall (mm) per month 2008 to 2018, in Belém do Pará. Source: authors (2021).

The concept of seasons for the Amazon region is different from other regions of Brazil. In general, there is the “dry period “(from July to October) and the” rainy period “ (from December to May), with the months of June and November being the transition periods.

In the behavior of the relative humidity of the air (Figure 10), it is possible to observe in the studied period, thus characterizing the constantly high relative humidity in the city of Belém do Pará. Among the analyzed period, the years 2008, 2009, 2017 and 2018 stand out as the largest records.

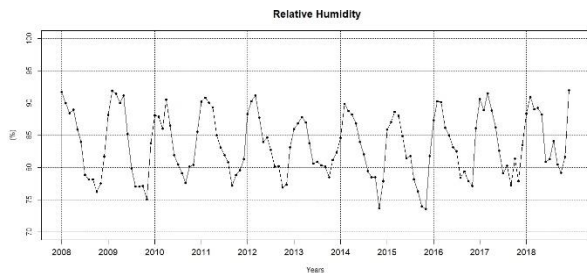


Figure 10 - Relative air humidity time series (%) in the years 2008 to 2018, for the study region. Source: authors (2021).

Figure 11 shows the graph of monthly variability of the relative humidity variable, and it is possible to observe that the highest value is present in February (89.51%) and the lowest value in November (77.72%), with a transition period from April to May for drought periods, as a transition to the rainy season.

This element is closely related to the distribution of rainfall and air temperature over the years. The monthly distribution of relative humidity is related to the distribution of rainfall, and that the highest values of humidity occurred in the months of highest rainfall.

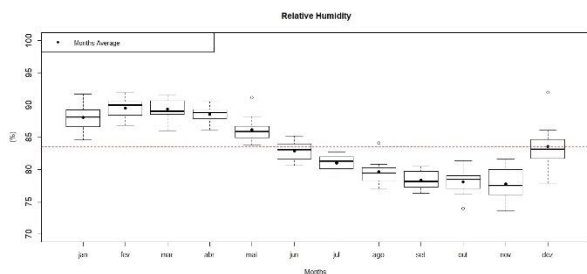


Figure 11 - Boxplot of relative humidity (%) by month 2008 to 2018, in Belém, Pará. Source: authors (2021).

It is verified that the variability of the wind speed that is represented in Figure 12, presents higher values in the years of 2008 to 2010, highlighting the year of 2009 where the highest value of 2.5 (m/s) was recorded and lower values in the years of 2012, 2016 and 2018 being less than 1.5 (m/s).

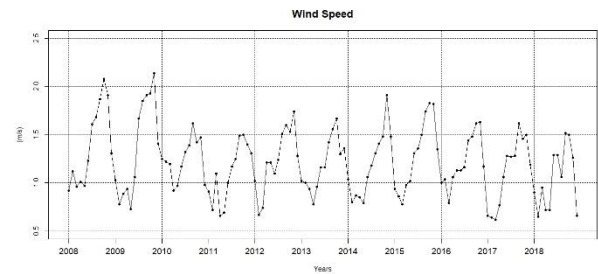


Figure 12 - Time series of wind speed in the years 2008 to 2018, PA. Source: authors (2021).

It is observed for Belém / PA that there is a predominance of calm (83.3%), followed by weak winds with speed classes of 1.0 to 2.0 m/s (3.9%), categorized as light breeze circulation, as stated by the Beaufort scale (WMO, 2000). On the authority of the World Meteorological Organization (WMO) the calm situation is considered when the wind magnitude is less than 1 node 0.515 (m/s). Seasonally, there is a variation in average speed, between 0.90 and 1.50 (m/s).

The wind speed variable (Figure 13) also shows a well-defined annual cycle, where it is possible to observe that in November it presents the highest recorded value 1.64 (m/s), and lower values in February reaching 0.86 (m/s).

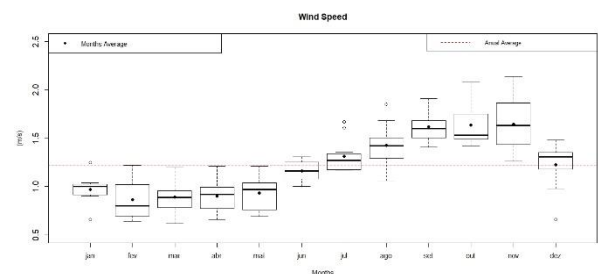


Figure 13 - Boxplot of wind speed by month 2008 to 2018, in Belém do Pará. Source: authors (2021).

Table 1 - Marginal model of generalized estimation equations (GHG), between meteorological variables and hospitalizations for Acute Myocardial Infarction, in Belém do Pará, 2008 – 2018. Source: authors (2021).

Variables	Estimate	Error	p-value	RR*
Maximum Temperature	0.24	0.060	<0.001	1.27
Wind speed	-0.35	0.187	<0.1	0.70

Legend: Significance 5%, RR* = Relative risk.

The result of the modeling via generalized estimation equations is observed in Table 1, where there is a significant statistical association between hospitalizations for Acute Myocardial Infarction and meteorological variables: Maximum air temperature and wind speed. Thus, it is accepted the hypothesis that the synergy between high air temperature values contributes to the increase in the number of hospitalizations for AMI, while the relationship between wind speed and the disease occurs inversely. It is noteworthy that because it is the maximum temperature, these negative effects may be greater in the afternoon, since this is the period when the highest temperatures are reached in the city under study.

Among the other meteorological variables analyzed: relative humidity, precipitation, and minimum air temperature, there were no significant relationships in relation to hospitalizations. However, since humans are permanently in contact with the atmosphere, they change its dynamics and thus become victims of the influence they exert on the environment. With this, some diseases arise or develop due to natural or anthropogenic variations in frequent climatic elements.

The results of this study corroborate with those of Keatinge (1986) and Sharovsky (2001), where the authors affirm the existence of a direct relationship between the maximum air temperature and the number of cases of AMI, that is, when there is a sudden increase in air temperature, the number of hospitalizations increases.

On the report of Keatinge et al.¹¹ (1986), the increase in temperature causes a severe sweat that leads to a decrease in plasma volume and a drop in blood pressure, in addition to increasing blood viscosity, the number of hamacias and platelets, which may become involved in atheromas that interrupt the blood flow to the tissues, thus causing AMI, depending on the organ affected.

Another relevant contribution in this area was the study by Murara (2010), where it is termed that variations in weather types influence body temperature, since they activate the natural (homeostatic) human mechanisms for domain of stability between the external environment and the internal organism. Since the healthy human body shows greater effectiveness at a temperature of 37 °C (Thermal Equilibrium). The human organism responds to this process by activating the functioning of vasoconstriction and vasodilation, overload or lower flow of blood vessels and the heart (TORTORA, 2000). Thus, this usually occurs with the increase in blood pressure, being able to proceed in the highest incidence of circulatory diseases.

4. FINAL CONSIDERATIONS

About 4242 cases of hospitalizations for Acute Myocardial Infarction were recorded in the study period and it was observed that in the years 2016 and 2018 there was a considerable increase in the rate of hospitalizations. The modeling showed significant associations between independent variables (maximum temperature and wind speed) and dependent variables (hospitalizations). Therefore, in Belém do Pará between the periods of 2008 to 2018, the change in maximum temperature and wind speed contributed to a higher risk of hospitalizations of the population for Acute Myocardial Infarction.

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