Impact of heat waves on cardiovascular and respiratory morbidity and mortality in municipalities of Northeast Brazil

Impacto das ondas de calor na mobilidade e mortalidade cardiovascular e respiratória em municípios do Nordeste do Brasil

Nelson Bernal [1]

Lara Schwarz [2]

Tarik Benmarhnia [3]

Saulo Rodrigues Filho [4]

[1] PhD in Sustainable Development, Postdoctoral Researcher, Center for Sustainable Development (CDS), University of Brasilia (UnB), Brasilia, DF, Brazil
E-mail: neleduberdav@gmail.com

[2] Master of Public Health, Ph.D. Student, School of Public Health, San Diego State University, San Diego, CA, USA
E-mail: laranschwarz@gmail.com

[3] PhD in Epidemiology, Permanent Professor, School of Public Health and the Institute of Oceanography at the University of California, San Diego, La Jolla, CA, USA
E-mail: tbenmarhnia@ucsd.edu

[4] PhD in Natural Sciences, Adjunct Professor, Center for Sustainable Development (CDS), University of Brasilia (UnB), Coordinator of the Regional Development Sub-Network of the Climate Network, Brasilia, DF, Brazil
E-mail: saulofilhocds@gmail.com

doi:10.18472/SustDeb.v13n2.2022.42228

Received: 07/03/2022
Accepted: 20/07/2022

ARTICLE – VARIA

ABSTRACT
In the last few years, many studies have researched the impacts of heat waves on population health. However, very few focus on the Brazilian context. This study aims to analyse the impact of heat waves on the cardio-respiratory health of the northeastern population, analysing how heat waves from October to March increase the risks of morbidity and mortality in the population of five municipalities. It is observed that January, February and October present more morbidity and mortality cases in the population and that the municipality of Belém del San Francisco presents the highest odds of increased health risk from heat waves. Additionally, a positive signal was found between heat waves and cardiovascular hospitalisations for many heat wave definitions. A time stratified cross-case design was used to study the association between heat waves, deaths, and hospitalisations.

Keywords: Heat waves. Temperature. Variability. Mortality. Morbidity. Health impacts.

RESUMO
Nos últimos anos, um grande número de estudos tem sido gerado sobre os impactos causados pelas ondas de calor na saúde da população, porém, muitos deles fora do país. Esse estudo tem como objetivo analisar o impacto das ondas de calor na saúde cardiovascular e respiratória da população nordestina, analisando como as ondas de calor de outubro a março aumentam os riscos de morbimortalidade da população de cinco municípios. Observa-se que os meses de janeiro, fevereiro e outubro são os que mais apresentam casos de morbimortalidade da população e, que o município de Belém do São Francisco, apresenta a maior probabilidade de risco. Além disso, um sinal positivo consistente foi encontrado entre as ondas de calor e a hospitalização cardiovascular. Metodologicamente, foi usado um desenho cruzado estratificado de casos para estudar a associação entre onda de calor e óbitos e hospitalizações.

Palavras-chave: Ondas de calor. Temperatura. Variabilidade. Mortalidade. Morbidade. Impactos na saúde.

1 INTRODUCTION

Heat waves adversely affect human health and drive increased deaths (ALCALÁ, 2019; ANDERSON, 2009; ARMSTRONG, 2014; GUO, 2017; NATIONAL, GUERRERO, 2018; PÉRES, 2020). This was evident after the intense heat wave that affected 16 European countries in 2003 and caused the death of 70,000 people. According to a study by Alcalá (2019), the magnitude, duration and intensity of heat waves increased globally between 2003 and 2018. The authors show that in 2018 heat waves recorded in Asia, North America, Europe, and Oceania caused 1,500 deaths globally.

This article aims to analyse the impact of heat waves on the cardiovascular and respiratory health of the northeastern population of Brazil. We analysed how heat waves from October to March increased the risks of morbidity and mortality in the population of five municipalities. Many studies have shown that the variability of air temperature (AT) and heat waves affect morbidity and mortality rates and particularly those that are most vulnerable (ANDERSON, 2009; ARMSTRONG, 2014; BERNAL *et al.*, 2014; GREEN *et al.*, 2015; GUO, 2017; LI *et al.*, 2015). In Brazil, some studies have shown an association between heat waves, air temperature and mortality, and socioeconomic characteristics of the population can drive increased vulnerability (GEIRINHAS *et al.*, 2020). According to these studies, in different parts of the country, temperature and humidity influence general mortality indicators and specific causes. Other studies indicate that heat waves generate a series of impacts on human health in various regions studied (BAUTISTA *et al.*, 2011; CARVER; SHEIER, 2014; ERCIDES, 2020; GEIRINHAS *et al.*, 2019; GUO *et al.*, 2015; IKEFUTI, 2018; LAERTE *et al.*, 2016; SILVEIRA *et al.*, 2019).

Silveira *et al.* (2019) investigated the total effect of temperature on cardiovascular mortality in 27 Brazilian cities, for example, and demonstrated the existence of risks associated with temperature. They show that cardiovascular mortality is associated with low and high temperatures in most cities in Brazil. Zhao *et al.* (2019) quantified the relationship between heat and hospitalisation by the time of year and the climatic conditions of 1,642 cities during the hot seasons of 2000-2015, showed that the number of hospitalisations was associated with average daily temperature, increasing in the season late warm compared to the early warm season. The author highlights that this effect is registered similarly between women and men. However, people older than 75 years are more affected.

Laerte *et al.* (2016) evaluated the effect of climatic seasonality on respiratory symptoms in the tropical city of Goiânia (GO) and observed that the number of individuals with respiratory symptoms increased significantly with the reduction of relative humidity, which the analysis of regional meteorological data could predict. On the other hand, Ikefuti (2018) evaluated the associations between stroke and air temperature from 2002 to 2011 in São Paulo and showed that air temperature increased mortality from stroke for both men and women.

Analysing the impact of heat waves on the cardiorespiratory health of the population, the World Health Organization (WHO) states that the climate and its abrupt variations have an essential role in the mortality and morbidity of the population (ALCALÁ, 2019; SURVEILLANCE, 2004; WHO, 2014), showing that the climatic factor constitutes a risk factor for the health of vulnerable populations. It is estimated that abrupt temperature variability and the emergence of heat waves, as a result of climate change, will drive increases in mortality and morbidity of the population in the coming years (ALCALÁ, 2019; SURVEILLANCE, 2004). Therefore, it will be necessary to carry out specific studies to generate adaptation measures and early local warnings to generate resilience for affected populations (CONLON *et al.* 2011; KINGDOM, 2011). Therefore, understanding the most relevant thresholds to reveal the impact of heat waves on health is essential, making it possible to activate early warning systems and protect the population effectively.

Studies carried out in Brazil studying the health impacts of heat have predominately focused on the country's main cities, with little attention to smaller cities where social and economic conditions may differ. Therefore, it is crucial to carry out studies in these areas to generate scientific data that contribute to the generation of early warnings in these regions. By generating evidence on the risk factors in these cities, local authorities can take the corresponding actions to improve the health services and protect population health (LUCCHESE, 2004; MACHADO *et al.* 2017). The research results can also increase the knowledge of the impacts of climatic phenomena related to temperature on morbidity and mortality in semi-arid regions of Brazil, enabling the generation of public policies that help health service providers and the local population to better face these human health threats.

2 STUDY AREA

The San Francisco basin in Brazil is considered one of the most important in the country because, firstly, it is one of the largest in the region and also because it has relevant economic, cultural and social importance, particularly for the population settled in the Northeast and Southeast region of the country. The river has a drainage area of 634,781 km^2, representing 8% of the national territory, covering 503 municipalities and forming part of seven States of the Federation: Bahia, Minas Gerais, Pernambuco, Alagoas, Sergipe, Goiás and the Federal District. The basin is divided into four physiographic sub-regions (Upper mid, sub mid, mid and lower San Francisco) and has been affected by prolonged droughts and extreme aridity (HERMUCHE, 2002).

Each of the four physiographic regions of the basin is characterised by different types of climate, soil and vegetation cover. This study was carried out in municipalities that correspond to the Submédio de San Francisco (SubM-SF), which has a semi-arid and arid climate and registers an average annual rainfall that ranges between 800 and 350 mm and an average annual temperature of 27º C., 2,800 hours of sunshine, and 1,550 mm of average annual evapotranspiration (MOURA *et al.*, 2006).

The SubM-SF region is characterised by water scarcity, climatic extremes, unpredictable rainfall and high evapotranspiration (MARENGO *et al.*, 2018; SHUKLA, 1981). Maximum and minimum temperatures of the studied area occur during November and July, respectively, registering a maximum temperature of 28.05o C and a minimum of 22.89º C.

This research analysed the impact of heat waves on the health of the population living in the municipalities of Belém do São Francisco, which has 20,253 inhabitants according to the 2010 census, Floresta with 29,285, Itacuruba with 4,369, and Petrolândia with 32,492, Jeremoabo with 37,680 and Paulo Afonso with 108,396 inhabitants. These territories correspond to the states of Bahia and Pernambuco (Figure 1).

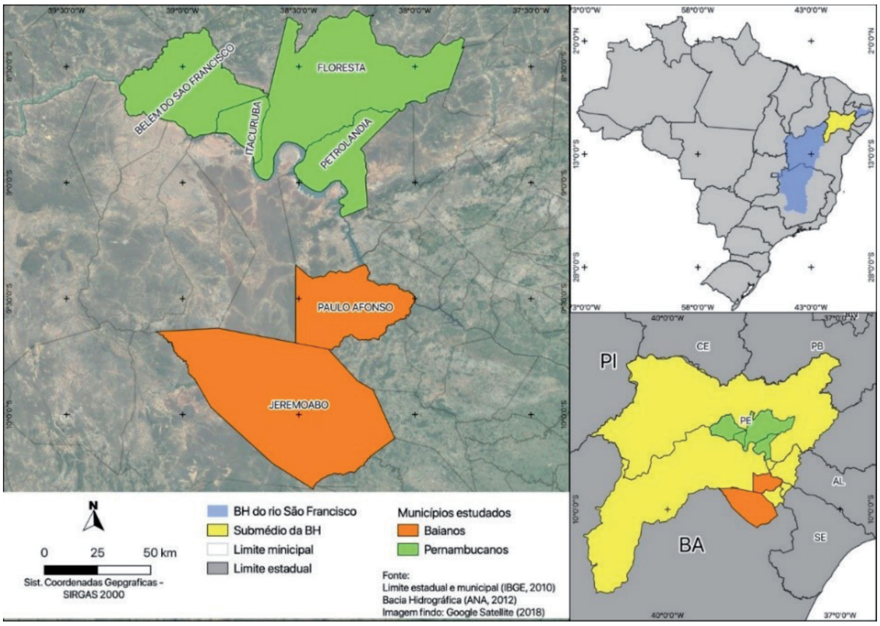

Figure 1 | Map of the study area in the Sub-Medium region of San Francisco.

Source: Authors elaboration.

3 METHODS

Since 2018, the Brazilian Climate Change Research Network (REDE CLIMA for its acronym in Portuguese) and the Socio-environmental Dynamics Observatory (INCT – ODISSEIA) have been conducting field research together with indigenous peoples and communities of the Sub-Medium region of the San Francisco Basin to analyse the impacts that climate change has been causing on the local population.

In this case, the objective of this research was to evaluate the effect of climatic seasonality on the occurrence of hospitalisations and deaths of patients with cardiovascular and respiratory diseases treated at a local Basic Health Unit (UBS) (See Table 1). The study was developed from the analysis of primary data from the period (January 2008 to September 2019), which were provided by the General Coordination of Information and Epidemiological Analysis (CGIAE), the area responsible for the Mortality Information System (SIM) of the Ministry of Health of Brazil.

In this study, a heat wave event was defined as when the maximum temperature exceeds a percentile threshold (99, 97.5 or 95) of the temperature distribution for each region within a specific month or season from January 2008 to March 2019. The heat wave defined by the days of extreme heat within the spring and summer seasons (October-March) were considered for this analysis. Monthly heat wave definitions were also created and defined as the temperature exceeding the percentile threshold per month, considering days of extreme heat each month. All definitions were considered as one- or two-day heat wave events when the temperature reaches the percentile threshold (99, 97.5, or 95) for two consecutive days. These various definitions were taken into account to determine the ideal measure for heat waves and determine in which months or seasons the strongest associations are observed. September was omitted because this month was considered a transition month with the coldest season of the year, winter.

Regarding the statistical analysis, a time stratified case-crossover design was used to study the association between each definition of a heat wave and deaths and hospitalisations of cardiovascular and respiratory diseases (BASU, 2008; BASU; OSTRO, 2008; TONG, 2012). The methodology is similar to the design and analysis of a case-control study. However, here the controls are identified for the same individual as the cases in the study population; therefore, only variables that vary over time are considered covariates. Control days were selected based on the same day of the week of admission to the hospital within the same month and year in which the case occurred. Percentiles (97.5 and 99) were chosen for the definitions of heat wave events for this analysis to identify days of extreme heat.

A conditional logistic regression model was used to study the association between heat waves, deaths, and hospitalisations for each definition of a heat wave and hospitalisation diagnosis. Precipitation was used as a covariate to adjust for humidity, and each heat wave definition and hospitalisation diagnosis for the entire region and each municipality were analysed separately.

We also analysed the climatic variability of the municipalities addressed between the period (1989 - 2019). This was done with geospatial satellite data corresponding to NASA's *The Power Project*. Primary solar and meteorological data sources made available by NASA are natively produced on a 1° x 1° global latitude/longitude grid and resigned to a 0.5° x 0.5° latitude/longitude grid by interpolation or bilinear replication (THE POWER PROJECT, 2020). Once the data had been analysed, they were compared to the results of other regional studies to confirm the deductions obtained (GAIVIZZO *et al.*, 2019; MARENGO, 2009; RODRIGUES FILHO, 2016; SILVA *et al.*, 2011; TEIXEIRA, 2016).

The climatic data acquired were analysed by associating the number of deaths and hospitalisations of the local population, and the results obtained in the regression could inform future risks related to heat waves.

It should be noted that this study complies with the standards and requirements of the Research Ethics Committee of the Faculty of Human and Social Sciences of the University of Brasilia (UnB), which is duly registered in process No. 01037218.5.0000.5540 and opinion of approval No. 3,440,596.

4 RESULTS

4.1 CLIMATE VARIABILITY IN THE STUDIED REGION

As stated, several studies show how climatic factors can harm vulnerable populations' health, which demonstrates the importance of studying how temperature variability and heat waves can play a role in increasing mortality and morbidity. It is believed that there will be an increase and decrease in temperatures in the coming years due to climate change in some seasons of the year, driving increases in mortality (CONLON *et al.* 2011; KINGDOM, 2011).

Therefore, it becomes relevant to carry out evaluations of these temperature extremes to generate projections of health impacts and to generate adaptation measures to promote resiliency for affected populations.

A slight increase in temperatures is observed from 1989 - 2019 in the region studied, reaching an annual average of 0.5º C (See Figure 2). The year with the lowest temperature was 1989, reaching 25.42º C; the hottest was 1998, when 27.08 º C was recorded.

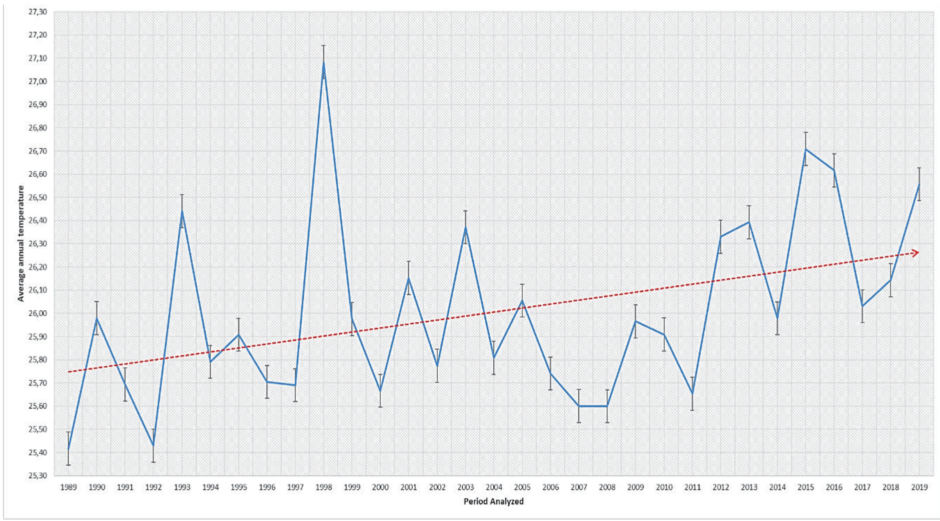

Figure 2 | Variation in the average annual temperature recorded in the study area, 1989 - 2019.

Source: Authors' elaboration, with data from NASA Prediction of Worldwide Energy Resources (Power). Higher Resolution Daily Time Series by Location 1/2 x 1/2 degree.
Climatology Resources for SSE - Renewable Energy. Bottom-left Latitude: -10.2640 Longitude: -39.0400. Upper-right Latitude: -8.4705 Longitude: -38.0270.

The maximum and minimum temperatures recorded corresponded to November and July, and we can more clearly observe an increase in the average temperature in these months (See Figure 3). For example, in the first years of the analysed period, it is observed that the average temperature for November was 27.7º C, a value that went to 28.6º C in recent years, showing an increase of approximately (1º C).

Concerning the variability of the lowest temperature recorded in July, in the same way, we observed a slight increase throughout the analysed period. In the first years, the average reached 22.5º C and the later years registered 23.4º C. Temperature variation can influence the increase or decrease in morbidity cases and mortality in the local population; the figures below show the historical temperature exposure for the region.

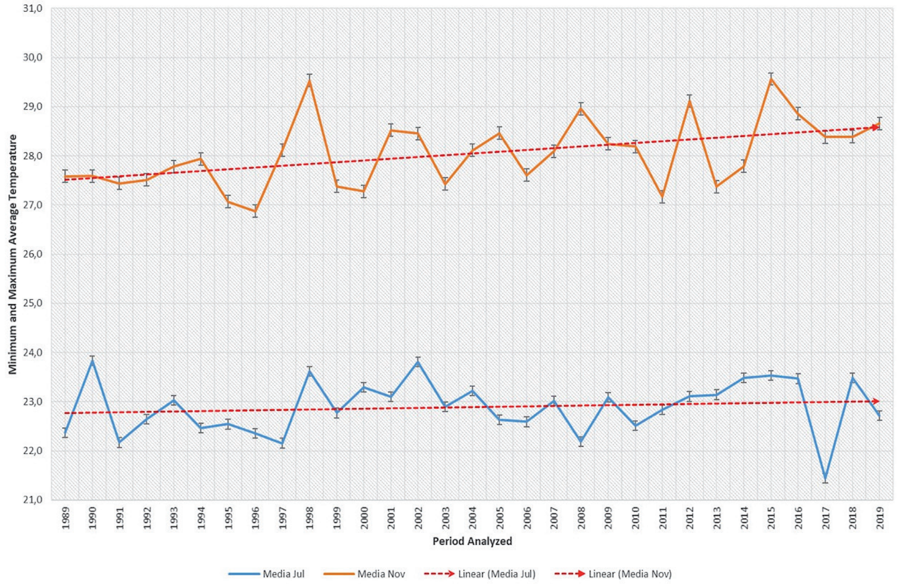

Figure 3 | Variation in the average annual temperature recorded in the study area, 1989 - 2019.

Source: Authors' elaboration, with data from NASA Prediction of Worldwide Energy Resources (Power). Higher Resolution Daily Time Series by Location 1/2 x 1/2 degree.
Climatology Resources for SSE - Renewable Energy. Bottom-left Latitude: -10.2640 Longitude: -39.0400. Upper-right Latitude: -8.4705 Longitude: -38.0270.

4.2 HEAT WAVES, MORBIDITY AND MORTALITY OF THE LOCAL POPULATION

Our study population included 22,896 hospitalisations and 1,265 deaths in the municipalities of Belém do São Francisco, Floresta, Itacuruba, Petrolândia, Jeremoabo and Paulo Afonso territories corresponding to the states of Bahia and Pernambuco from January 2008 to September 2019 (See Table 1).

Table 1 | Description of total hospitalisations and deaths both diseases. 2008-2019

Municipality	Hospitalizations for both diseases	Deaths (%)
Belém de São Francisco	1229 (43.0)	19 (47.4)
Floresta	3491 (43.9)	128 (49.2)
Itacuruba	175 (46.9)	twenty
Jeremoabo	1553 (39.0)	104 (39.4)
Paulo Afonso	12,120 (43.6)	917 (47.3)
Petrolândia	4,328 (42.8)	95 (45.3)
TOTAL	22,896	1,265

Source: Prepared by the authors with data from the General Coordination of Information and Epidemiological Analysis (CGIAE).

Table 2 | Description of definitions of heat waves by summer period

For summer period				
Season	Definition of heat wave	Threshold percentile and median temperature (°C)	Duration (days)	Number of days by municipalities
summer	HWD1	99 (31.7)	1	123
summer	HWD2	99 (31.9)	2	51
summer	HWD3	97.5 (31.3)	1	317
summer	HWD4	97.5 (31.5)	2	155
summer	HWD5	95 (30.9)	1	617
summer	HWD6	95 (31.1)	2	347

Source: Elaboration of the authors.

The temperature thresholds for the definitions of heat waves and the number of heat waves that occurred are described in Table 2. The lowest threshold for temperature in all municipalities had an average of 29.9ºC for the two-day heat waves defined at per cent 99 in January. The highest of all heat wave definitions was 32.5ºC for 2-day heat waves, defined at 97.5 per cent in November (See Table 3).

Table 3 | Description of definitions of heat waves by month

Per month				
Season	Definition of heat wave	Threshold percentile and median temperature (°C)	Duration (days)	Number of days by municipalities
October	HWD1o	99 (31.2)	1	21
October	HWD2o	99 (32.1)	2	5

ISSN-e 2179-9067

Per month				
Season	*Definition of heat wave*	*Threshold percentile and median temperature (°C)*	*Duration (days)*	*Number of days by municipalities*
October	HWD3o	97.5 (30.9)	1	54
October	HWD4o	97.5 (31.0)	2	21
October	HWD5o	95 (30.5)	1	106
October	HWD6o	95 (30.7)	2	57
November	HWD1n	99 (32.4)	1	22
November	HWD2n	99 (32.5)	2	8
November	HWD3n	97.5 (31.7)	1	50
November	HWD4n	97.5 (32.5)	2	8
November	HWD5n	95 (31.3)	1	99
November	HWD6n	95 (31.5)	2	46
December	HWD1d	99 (31.6)	1	16
December	HWD2d	99 (31.0)	2	4
December	HWD3d	97.5 (31.6)	1	53
December	HWD4d	97.5 (31.7)	2	23
December	HWD5d	95 (31.4)	1	107
December	HWD6d	95 (31.6)	2	65
January	HWD1e	99 (30.9)	1	20
January	HWD2e	99 (29.9)	2	2
January	HWD3e	97.5 (30.5)	1	56
January	HWD4e	97.5 (30.7)	2	21
January	HWD5e	95 (30.2)	1	117
January	HWD6e	95 (30.7)	2	21
February	HWD1f	99 (30.6)	1	20
February	HWD2f	99 (30.6)	2	2
February	HWD3f	97.5 (30.5)	1	49
February	HWD4f	97.5 (30.6)	2	24
February	HWD5f	95 (30.2)	1	96
February	HWD6f	95 (30.4)	2	53
March	HWD1m	99 (31.24)	1	21
March	HWD2m	99 (31.3)	2	9
March	HWD3m	97.5 (30.7)	1	57
March	HWD4m	97.5 (30.8)	2	27
March	HWD5m	95 (30.4)	1	109
March	HWD6m	95 (30.5)	2	63

Source: Elaboration of the authors.

When exploring the association between heat wave days, hospitalisations and deaths, there was some variability, observing a positive signal between heat waves and cardiovascular hospitalisation, particularly in two-day heat waves (See Figure 4). The results mainly show us that heat waves cause a greater effect on cardiovascular morbidity, mainly the day after the heat wave and in heat waves lasting two days. In the case of respiratory morbidity, the data show a slight impact. However, the results were imprecise.

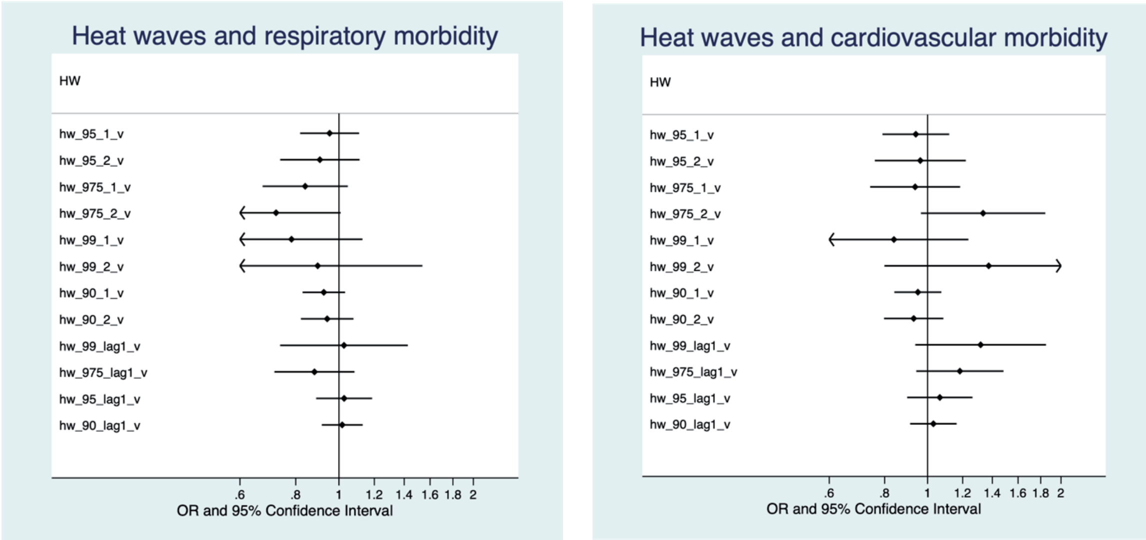

Figure 4 | Impact of heat waves on cardiovascular and respiratory morbidity.
Source: Elaboration of the authors. Results of time-stratified crossover case analysis.

Because our analysis's sample of deaths was small, we focused on hospitalisations as the primary outcomes. We generally find more impact from heat waves defined by month than those defined by the whole period. For example, in January, we observed a higher risk of hospitalisation in the population when heat waves are recorded (Figure 5). As can be seen, the effects of heat waves are positive at the beginning of January, February and October, during which there would be a greater probability of cardiovascular and respiratory hospitalisations.

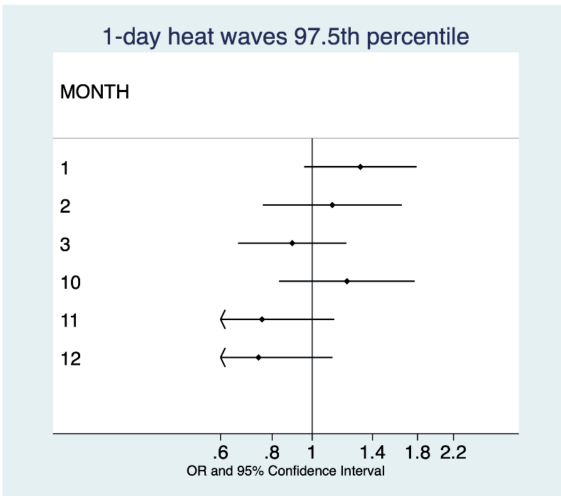

Figure 5 | Heat wave impact defined by month for 1-day heat waves at the 97.5 percentile
Source: Elaboration of the authors. Stratified crossover case analysis.

Considering the results by municipality, we observe that the population most exposed and prone to respiratory and cardiovascular problems from heat waves in these periods are in the municipality of Belém do Sao Francisco, with an odds ratio of 1.85 (95% CI: 0.99, 3.43).

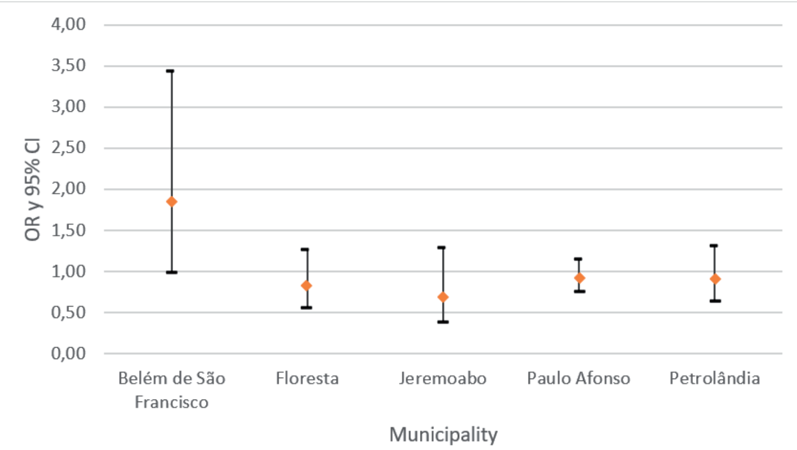

Figure 6 | Effect of heat waves by department

Source: Authors' elaboration, results of time-stratified crossover case analysis.

5 DISCUSSION AND CONCLUSION

The analysis of health data obtained at the municipal level shows us that heat waves from October to March influence the number of morbidity cases in the northeastern population, particularly in Belém do São Francisco. Therefore, this municipality should prepare to respond to the increase in cases as temperature increases are expected.

The analysis of regional climate variability shows us an increase of approximately 1º C from 1989 to 2019. This could have increased the number of cases in recent years, mainly in the months that show the highest number of cases, since, as can be seen, there is an abrupt temperature variability (See Figure 3).

The increase in cases in certain months could be driven by abrupt temperature variation and heat waves (ANDERSON, 2009; ARMSTRONG, 2014; BAUTISTA *et al.*, 2011; CARVER; SHEIER, 2014; GEIRINHAS *et al.*, 2019; GUO, 2017; GUO *et al.*, 2015; IKEFUTI, 2018; SILVEIRA *et al.*, 2019). For example, Silveira *et al.* (2019) observed the effect of temperature and heat waves on cardiovascular mortality in 27 Brazilian cities.

Socioeconomic or physiological factors can increase vulnerability to extreme heat, making it essential to promote policies that aim to reduce existing risks with health services and social-economic disparities (ERCIDES, 2020; SARRÓ, 2009). Housing, work and population dynamics can also play a role in the impacts observed; illegal settlements where improvisation of access to basic services is common in this region can also increase their health risk increasing vulnerability to climatic stressors (YANG *et al.*, 2019).

This point could not be evaluated in the present investigation due to the objective and the data analysed. However, we consider that it would be advantageous to analyse in future work since they would better help to see the effects of heat waves on population health. One of the limitations encountered in order to analyse the problem exposed in this work, comparing it to other similar realities, was the limited existence of studies carried out in Brazil and in the region, for which it is considered necessary to generate more epidemiological evidence to corroborate what was stated and reduce the vulnerability of the affected population. Additionally, obtaining data on mortality and morbidity by the municipality was another limitation, restricting the study to only be carried out in six of the fifteen municipalities for which information was requested.

It is essential to consider improvements in the recording and dissemination of data that can be used to carry out this type of analysis and find a solution to these uncertainties, as well as the establishment of regional and municipal early warnings, with emphasis on the months of greatest risk. This would help make it possible to generate a better response from health services and a reduction in the number of hospitalisations.

The quality of care in health service establishments also affects the number of deaths and the population's health. The most common is the precariousness of material and professional resources faced by the health area, mainly in Latin American countries. This was observed in this last health crisis, showing how a lack of resources led these centres to a rapid collapse in the face of Covid-19 (GARCIA, 2020; LUCCHESE, 2004; WHO, 2020). Moreover, studies have shown that these deficiencies increase the health risks for patients (CECCHERINI *et al.*, 2016; EBI, 2011; FRUMKIN *et al.*, 2008; VAN LINDEN *et al.*, 2015).

In conclusion, we think it is pertinent to identify the most critical periods for temperature increases, morbidity and mortality of the population in different areas of the country, calling the attention of local and municipal authorities to take actions that guarantee adequate equipment and health care to reduce this health burden which will only be accentuated in the context of climate change.

ACKNOWLEDGMENT

This work is part of the research activities of the CLIMA Network (Regional Development Sub-network) and the INCT/Odisseia project (Observatory of socio-environmental dynamics: sustainability and adaptation to climatic, environmental and demographic changes), dependent on the National Institutes and Science and Technology Program (Call INCT – MCTI/CNPq/CAPES/FAPs n.16/2014). Likewise, the technical and scientific support of specialists from the School of Public Health of the University of California, San Diego, CA, USA is gratefully acknowledged. This work was funded by Capes (Coordination for the Improvement of Higher Education Personnel), CNPq (National Council for Scientific and Technological Development) and FAP-DF (Federal District Research Support Foundation).

REFERENCES

ALCALÁ, P.; SALLY, E. **Ola de Calor y Medidas a Tomar:** revisión preliminar. Organización Panamericana de la Salud (OPS)/Emergencias en Salud Biblioteca, n. 1, p. 6-8, 2019.

ANDERSON, B. G.; BELL, M. L. Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. **Epidemiology**, v. 20, n. 2, p. 205-213, 2009. PMID: 19194300, DOI: https://doi.org/10.1097/EDE.0b013e318190ee08.

ARMSTRONG, B.; GASPARRINI, A.; HAJAT, S. Estimating mortality displacement during and after heat waves. **Am J Epidemiol**., v. 179, n. 12, p. 1405-1406. 2009, PMID: 24812157, DOI: https://doi.org/10.1093/aje/kwu083.

BASU, R. *et al.* Characterising Temperature and Mortality in Nine California Counties. **Epidemiology**, p. 138-45, 2008.

BASU, R.; OSTRO, B. D. A Multicounty Analysis Identifying the Populations Vulnerable to Mortality Associated with High Ambient Temperature in California. **American Journal of Epidemiology**, p. 632–76, 2008.

BAUTISTA, F. *et al.* **Software to identify climate change trends at the local level:** a study case in Yucatán, México. 2011. Available in: http://www.chapingo.mx/revistas. Access in: July 12, 2018.

BERNAL, N. F. *et al.* The Source of Halogens in Geothermal Fluids from the Taupo Volcanic Zone, North Island, New Zealand. **Geochimica et Cosmochimica Acta**. p. 126, 2014.

CARVER, C.; SHEIER, M. **Red Tercer Milenio Teorías de la Personalidad**. 2014. Available in: http://www.aliat.org.mx/BibliotecasDigitales/Psicologia/Teorias_de_la_personalidad.pdf. Access in: July 12, 2018.

CECCHERINI, G. *et al.* Magnitude and Frequency of Heat and Cold Waves in Recent Decades: the case of South America. **Natural Hazards and Earth System Sciences**, v. 16, n. 3, p. 821-31, 2016.

CONLON, K. C. *et al.* Maturitas Preventing Cold-Related Morbidity and Mortality in a Changing Climate. **Maturitas**, v. 69, n. 3, p. 197-202, 2011. DOI: http://dx.doi.org/10.1016/j.maturitas.2011.04.004.

EBI, K. L. Resilience to the Health Risks of Extreme Weather Events in a Changing Climate in the United States. **International Journal of Environmental Research and Public Health**, v. 8, n. 12, p. 4582-95, 2011.

FRUMKIN, H. *et al.* Climate Change: the public health response. **American Journal of Public Health**, v. 98, n. 3, p. 435-45, 2008.

GAIVIZZO, L. *et al.* **Resiliência à mudança climática em comunidades de fundo de pasto na região semiárida do estado da Bahia, Brasil**. p. 1-22, 2019.

GARCIA, W. *et al.* Como o Brasil pode deter a Covid-19. **Epidemiol. Serv. Saúde**, v. 29, n. 2, p. 1-8, 2020.

GEIRINHAS, J. *et al.* Science of the Total Environment Characterising the Atmospheric Conditions during the 2010 Heatwave in Rio de Janeiro Marked by Excessive Mortality Rates. **Science of the Total Environment**, v. 650, p. 796-808, 2019. DOI: https://doi.org/10.1016/j.scitotenv.2018.09.060.

GEIRINHAS, J. Heat-Related Mortality at the Beginning of the Twenty-First Century in Rio de Janeiro, Brazil. **International Journal of Biometeorology**, v. 64, p. 1319-32, 2020.

GREEN, D. *et al.* Differential Effects of Temperature Extremes on Hospital Admission Rates for Respiratory Disease between Indigenous and Non-Indigenous Australians in the Northern Territory. **International Journal of Environmental Research and Public Health**, v. 12, n. 12, p. 15352-65, 2015.

GUO, Y. *et al.* **Heat wave and mortality:** a multicountry, multicommunity study, p. 1-11, 2015.

GUO, Y. *et al.* Heat Wave and Mortality: a multicountry, multicommunity study. **Environmental health perspectives**, v. 125, n. 8, 2017. 087006. ISSN 0091-676. DOI: 10.1289/EHP1026

HERMUCHE, P. **O Rio de São Francisco.** Companhia de Desenvolvimento dos Vales do São Francisco e do Parnaíba Potira Mei. (Cia. Desenvolv. dos Val. do São Fr. e do Parnaíba), 2002. 58 p. Available in: https://www.codevasf.gov.br/linhas-de-negocio/irrigacao/projetos-publicos-de-irrigacao/elenco-de-projetos. Access in: ago. 12, 2018.

IKEFUTI, P. *et al.* **Mean Air Temperature as a Risk Factor for Stroke Mortality in São Paulo**, p. 1535-42, 2018.

KINGDOM, U. **Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation**. IPCC. 2011.

LAERTE, J. *et al.* Efect of seasonality in hospitalizations for respiratory diseasein the city of Anápolis-GO between 2002 and 2012. **Rev. Educ. Saúde**, v. 4, n. 2, p. 31-42, 2016. Available in: http://periodicos.unievangelica.edu.br/index.php/educacaoemsaude/article/view/2014/1796.

LI, M. *et al.* Heat Waves and Morbidity: current knowledge and further direction-a comprehensive literature review. **International Journal of Environmental Research and Public Health**, v. 12, n. 5, p. 5256-83, 2015.

LUCCHESE, P**. Informação para tomadores de decisão em saúde pública** – ITD Políticas. Bireme/Opas/OMS Fiocruz Co. 2004.

MACHADO, C. *et al.* Health Policies in Brazil in Times of Contradiction: paths and pitfalls in the construction of a universal system. **Cadernos de Saúde Pública Sup**., v. 2, p. 33, 2017.

MARENGO, J. Impactos de Extremos Relacionados com o Tempo e o Clima – Impactos Sociais e Econômicos. **Boletim do Grupo de Pesquisa em Mudanças Climáticas** – GPMC v. 13, n. 8, p. 1-5, 2009.

MARENGO, J. *et al.* Climatic Characteristics of the 2010-2016 Drought in the Semiarid Northeast Brazil Region. **Anais da Academia Brasileira de Ciências**, v. 90, n. 2, p. 1973-85, 2018.

MCELROY, S. *et al.* Science of the total environment de fining heat waves and extreme heat events using sub-regional meteorological data to maximise bene fi ts of early warning systems to population health. **Science of the Total Environment**, p. 721, 2020. DOI: https://doi.org/10.1016/j.scitotenv.2020.137678.

MOURA, M. *et al.* **Rainfall and air temperature spatial variability of the sub-midde San Francisco***.* CONGRESSO BRASILEIRO DE METEOROLOGIA, 2006. 6p.

NATIONAL, S.; GUERRERO, P. **Impacto de la temperatura y las olas de calor en la mortalidad sobre Europa bajo escenarios de cambio climático.** XI CONGRESO INTERNACIONAL DE LA ASOCIACIÓN ESPAÑOLA DE CLIMATOLOGÍA (AEC): el clima: aire, agua, tierra y fuego. Normas para la presentación de comunicaciones escritas. (October). 2018.

ORGANIZACIÓN MUNDIAL DE LA SALUD (OMS). **Actualización de la estrategia frente a la Covid-19**. Organización Mundial de la Salud, v. 17. 2020.

PÉRES, W. E. *et al.* The Association between Air Temperature and Mortality in Two Brazilian Health Regions. **Climate** 2020, v. 8, n. 16. DOI: https://doi.org/10.3390/cli8010016

RODRIGUES FILHO, *et al.* **O clima em transe:** políticas de mitigação e adaptação no Brasil. 2016.

SARRÓ, R. La aventura como categoría cultural: apuntes simmelianos sobre la emigración subsahariana. **Revista de Ciências Humanas**, v. 43, n. 2, p. 501-21, 2009. Available in: http://www.periodicos.ufsc.br/index.php/revistacfh/article/view/2178-4582.2009v43n2p501.

SHUKLA, A. On the Dynamics of Droughts in Northeast Brazil: observations, theory and numerical experiments with a general circulation model*.* **Journal of the Atmospheric Sciences**, v. 38, p. 2653-2675, 1981.

SILVA, V. *et al.* Análise da pluviometria e dias chuvosos na Região Nordeste do Brasil. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 15, n. 2, p. 131-38, 2011.

SILVEIRA, I. *et al.* Science of the total environment the effect of ambient temperature on cardiovascular mortality in 27 brazilian cities. **Science of the Total Environment**, v. 691, p. 996–1004, 2019. DOI: https://doi.org/10.1016/j.scitotenv.2019.06.493.

SURVEILLANCE, COMMUNICABLE DISEASES; Roll Back Malaria. **Using Climate to Predict Infectious Disease Outbreaks:** a review, 2004.

TEIXEIRA, M. O sertão semiárido. Uma relação de sociedade e natureza numa dinâmica de organização social do espaço. **Sociedade e Estado**, v. 31, n. 3, p. 769-80, 2016.

TONG, S. *et al.* Assessing the Short-Term Effects of Heatwaves on Mortality and Morbidity in Brisbane, Australia: comparison of case-crossover and time series analyses. **PLoS ONE**, v. 7, n. 5, 2012.

VAN LINDEN, S. *et al.* The Scientific Consensus on Climate Change as a Gateway Belief: experimental evidence. **PLoS ONE**, v. 10, n. 2, p. 2-9, 2015.

WHO. **Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s**. 2014. Available in: http://www.who.int/globalchange/publications/quantitative-risk-assessment/en/.

WOLMIR, E. *et al.* **The association between air temperature and mortality in two brazilian health regions**, p. 1-14, 2020.

YANG, J.; CHENGHAO, W. **Population Dynamics Modify Urban Residents' Exposure to Extreme Temperatures across the United States**, p. 3-10, 2019.