THE EFFECTS OF HOT AND COLD TEMPERATURES ON HOSPITAL ADMISSIONS FOR RESPIRATORY DISEASES IN CAMPO GRANDE, MS, BRAZIL

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ABSTRACT - It examined the relationship between temperatures and hospital admissions for respiratory diseases in the city of Campo Grande, Brazil, during 2008-2014. A nonlinear model (DLNM) lag was used to examine the nonlinear effects of temperature on hospital admissions for respiratory diseases by age group. Nonlinear temperature effects were found in hospitalization for respiratory diseases by age group. Both hot and cold effects can last longer - a statistically significant relationship between the extreme temperatures and hospital admissions in all age groups in the gap. The heat had a greater impact on the elderly, while those aged 5-60 years were more sensitive to cold temperatures. The greatest risk of cumulative effects of heat was observed among those over 65 years at lag 0-25 (HR 1.509, 95% CI: 1.209 to 1.883), while those aged 65 years were at greater risk of exposure the extreme temperatures of cold lagged 0-25 (RR 1.482, 95% CI: 1.231 to 1.785). This study provides useful data for policymakers' decisions to better manage the health impacts of hot and cold temperatures.

KEYWORDS: hospital admission, respiratory, temperature, time series analysis, Brazil.

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RESUMO – Examinou a relação entre temperaturas e internações hospitalares por doenças respiratórias na cidade de Campo Grande, Brasil, durante 2008-2014. Foi utilizado um lag distribuídos do modelo não-linear (DLNM) para examinar os efeitos não lineares da temperatura sobre internações hospitalares por doenças respiratórias, por faixa etária. Os efeitos da temperatura não-lineares foram encontrados na hospitalização por doenças respiratórias, por faixa etária. Ambos efeitos quentes e frios podem durar mais tempo - uma relação estatisticamente significativa entre as temperaturas extremas e internações hospitalares em todos os grupos etários da lacuna. O calor teve um impacto maior sobre os idosos, enquanto aqueles com idade entre 5-60 anos foram mais sensíveis a temperaturas frias. Observou-se maior risco de efeitos cumulativos de calor entre aqueles com mais de 65 anos na lag 0-25 (HR 1.509, IC 95%: 1,209-1,883), enquanto aqueles com 65 anos estão sob maior risco de exposição a temperaturas extremas de frio defasada 0-25 (RR 1.482, IC 95%: 1,231-1,785). **Conclusões**: Este estudo fornece dados úteis para as decisões de gestores de políticas para gerenciar melhor os impactos na saúde de temperaturas quentes e frias.

PALAVRAS-CHAVE: admissão hospitalar, respiratória, temperatura, análise de séries temporais, Brasil.

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RESUMEN – Se examinó la relación entre las temperaturas y los ingresos hospitalarios por enfermedades respiratorias en la ciudad de Campo Grande, Brasil, durante 2008-2014. Se utilizó un intervalo distribuido del modelo no lineal (DLNM) para examinar los efectos no lineales de la temperatura en la hospitalización por enfermedades respiratorias por grupos de edad. Efectos de la temperatura no lineales fueron encontrados en la hospitalización por enfermedades respiratorias por grupos de edad. Ambos efectos calientes y fríos pueden durar más tiempo - una relación estadísticamente significativa entre las temperaturas extremas y los ingresos hospitalarios en todos los grupos de edad del intervalo. El calor tuvo un mayor impacto en los ancianos, mientras que los que tienen edad entre los 5 y 60 años eran más sensibles a temperaturas más frías. Se observó un mayor riesgo de efectos acumulativos de calor entre los que tienen más de 65 años en el intervalo 0-25 (HR 1,509, IC 95%: 1,209-1,883), mientras que los de 65 años están bajo mayor riesgo de exposición a las temperaturas extremas de frío de intervalo 0-25 (RR 1,482; IC del 95%: 1,231-1,785). **Conclusiones:** Este estudio proporciona datos útiles para las decisiones de los gestores de políticas para gestionar mejor los impactos en la salud de las temperaturas calientes y frías.

Palabras clave: ingreso hospitalario, respiratoria, temperatura, análisis de series temporales, Brasil.

INTRODUCTION

It is widely accepted that climate change is occurring and that it is caused mainly by increased emissions of anthropogenic greenhouse gases, particularly over the last few decades. Global mean temperature increased by 0.07 ºC per decade between 1906 and 2005, compared with 0.13 ºC per decade from 1956 to 2005 (IPCC 2014). Not only has the average global surface temperature increased, but the frequency and intensity of temperature extremes have also changed (IPCC 2014; WHO 2008). Heat wave episodes have been associated with significant health impacts worldwide (Armstrong et al. 2011; Aström et al. 2013; Knowlton et al. 2009; Bai et al. 2014; Michelozzi et al. 2009). In addition, episodes of extreme cold (cold spells) are a concern in high-latitude regions, such as Russia (Revich and Knowlton 2008), the Czech Republic (Kysely et al. 2009) and the Netherlands (Huynen et al. 2001).

The effect of ambient temperature on morbidity is a significant public health issue. Increased hospitalizations have been associated with exposure to extreme ambient temperatures, especially during heat waves and cold spells (Sun et al, 2019; Schwartz et al. 2004; Tian et al. 2019). Both heat- and cold-related morbidities occur more frequently among the elderly, as they are more vulnerable to temperature extremes (Knowlton et al. 2009; Kovats et al. 2004; Panagiotakos et al. 2004). In addition, urban residents are exposed to higher temperatures than residents of surrounding suburban and rural areas because of the "heat island effect" resulting from high thermal absorption by dark paved surfaces and buildings, heat emitted from vehicles and air conditioners, lack of vegetation, and poor ventilation (Barry Chorley 2003; Hajat Kosatsky 2010; O'Neill Ebi 2009). People living in urban areas have been found to be at a higher risk of morbidity from ambient heat exposure (Hajat Kosatsky 2010). The effect of temperature on morbidity is likely to become more severe as the number of elderly people increases (from 737 million persons >60 years old in 2009 to 2 billion by 2050 globally) and the proportion of urban residents increases (by approximately 18% of over the next 40 years). Furthermore, climate change will continue for at least the next several decades, even under the most optimistic scenarios (IPCC 2014).

Few studies have examined the impacts of temperatures on respiratory admissions in Campo Grande city, MS, Brazil (Souza et al 2014; Souza, A.; Fernandes et al. 2012.; Souza et al. 2016.; Souza, 2016.). It is necessary to quantify the relationship between temperature and respiratory diseases in order to better manage this increasing health problem. In this study, we examined the effects of temperature on respiratory hospital admission by age groups in Campo Grande city during 2008-2014.

METHOD

Study location

The city of Campo Grande, MS (20° 27'16 "S, 54° 47'16" W, 650 m) is located on the plateau called Maracajú-Campo Grande, 150 miles from the start of the largest floodplain in the world, the Pantanal (139 111 km^2), with an estimated population of 850,000 inhabitants (Ibge 2019; Souza et al. 2010). The climate in the region of Campo Grande, is the type with moderate temperatures ranging from 17.8 °C minimum, 29.8 °C maximum and average of 22.7 °C, rainfall annual average 1469 mm, average relative humidity is 72.8% and average elevation of 532 meters.

Data Collection

In this analysis, hospitalization data were collected from the Department of Informatics (DATASUS) of the health agencies of the Sistema Único de Saúde- SUS (Unified Health System). This system provides information that can serve to support objective analyzes of the health situation, evidence-based decision-making, and the design of health action programs.

The available data came from the Hospital Information System of SUS (SIH / SUS), managed by the Ministry of Health, through the Department in Health Care, in conjunction with the State Departments of Health and the Municipal Health and processed by DATASUS at the Executive Department of the Ministry of Health.

All hospitalizations occurred in the period between January 1, 2008 and December 31, 2014. The respiratory diseases investigated were coded according to the International Classification of Diseases (ICD) 10th Revision (ICD10, J10 to J18). We also stratified the respiratory morbidity by age groups (0-4, 5-60, and >60 years). It is noteworthy that the choice of this age group was according to the data records in the system, considering the stratification of the priority groups (children under five years old and the elderly). Daily weather data and ozone (O_3) concentration from same period in Campo Grande were obtained from the Institute of Physics, Federal University of South Mato Grosso (UFMS).

Statistical models

Studies have shown that the extreme temperature can not only affect current day's morbity but also influence the several following days' morbity (Braga et al. 2002; Zanobetti 2000; Guo et al. 2011). Also, the relationship between temperature and morbity is non-linear (Guo et al. 2011). In this study, a distributed lag non-linear model (DLNM) was fitted to examine the relationship between temperature and daily hospital admissions for respiratory diseases. The DLNM is developed on the basis of "cross-basis" function, which allows simultaneously estimating the non-linear effect of temperature at each lag and the non-linear effects across lags (Gasparini et al. 2010). Most recently, the method has been applied worldwide to identify a non-linear exposure–response association and delayed effects or harvesting (Bai et al. 2014).

We controlled for seasonality and long-term trend using a natural cubic spline with 7 df per year for time. The day of week was also included as an indicator in our analysis to control any confounding weekly pattern. Public holiday was controlled as a binary variable. We also control for relative humidity and ozone concentration. We evaluated the model fit using Akaike's Information Criterion for quasi-Poisson (Q-AIC). We used mean temperature to assess temperature effects in this analysis since it was found to be a better predictor (i.e. had lower Q-AIC values) than the maximum and minimum temperatures.

We used a DLNM with 5 degrees of freedom natural cubic for temperature (knots at equally-spaced percentiles by default) and with 4 degrees of freedom natural cubic for lags (knots at equally-spaced values in the log scale of lags by default) (24). The median value of the mean temperature (24.2 °C) was used as the reference value (centering value) to calculate the relative risks. A maximum lag of 25 was used to completely capture the overall temperature effect and adjust for a possible harvesting effect. We examined and plotted cumulative relative risks with temperature for lag 0, lags 0-2, 0-14 and 0-25.

Hot and cold effects separately on relative risks of age-specific hospital admissions for respiratory diseases, were also examined. For hot effects, we calculated relative risks associated with the 99th percentile of temperature (high temperature) relative to the 75th percentile of temperature. For cold effects, we calculated relative risks associated with the first percentile of temperature (cold temperature) relative to the 25th percentile of temperature. The cumulative effects of hot and cold temperatures along the lags were then estimated separately.

Sensitivity analysis were conducted by varying the df for time from 6-12 per year, the maximum lag days from 14-30 days, and the df for temperature and lags from 3 to 6. All statistical tests and modeling were preformed using the R software, version 3.0.1. Distributed lag non-linear models were fitted through "dlnm" package (Gasparini et al. 2010).

RESULTS

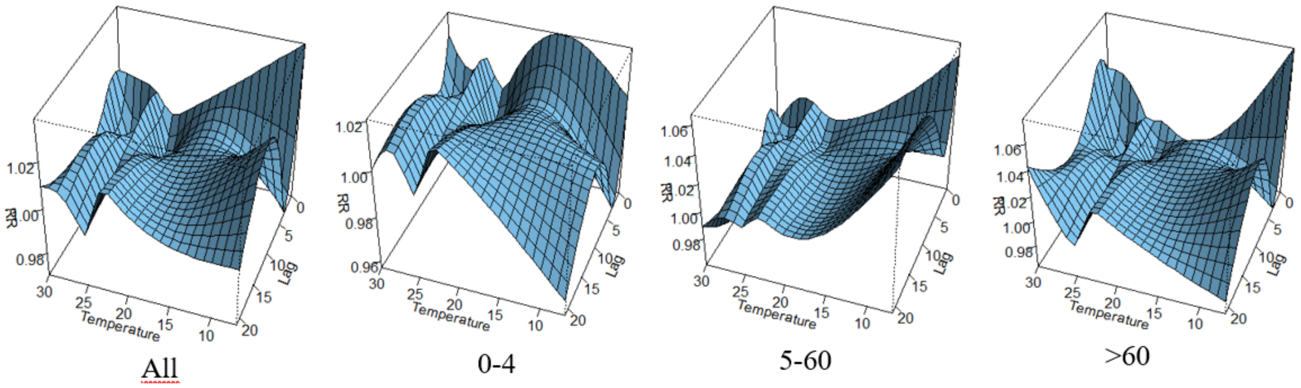
During the study period (January 1, 2008 to December 31, 2014) the total number of hospital admissions for respiratory diseases was 4486. Table 1 shows the statistical summary for hospital data, weather and ozone levels.

Table 1. Descriptive analysis of respiratory hospital admission, ozone, and weather conditions in Campo Grande, Brazil, during 2008 to 2014.

	Mean	SD	Min	25th	Median	75th	Max
Meteorological							
Mean temperature(°C)	23.50	3.51	7.00	22.10	24.20	25.73	30.81
Maximum temperature(°C)	30.07	3.87	10.90	28.40	30.80	32.59	39.50
Minimum temperature(°C)	18.85	3.62	4.30	17.30	19.90	21.39	26.88
Relative humidity (%)	66.06	16.12	19.16	55.00	67.81	78.83	98.00
Ozone	17.56	7.59	0.66	12.97	16.44	20.73	52.76
Respiratory hospital admission							
All	10.54	3.29	2.00	8.00	10.00	12.00	23.00
0-4 y	5.06	1.75	1.00	4.00	5.00	6.00	13.00
5-60 y	2.67	1.21	0.00	2.00	2.00	3.00	8.00
>60 y	2.80	1.07	0.00	2.00	3.00	3.00	7.00

Figure 1 shows the temperature effects of current day (lag 0) and cumulative effects on age-specific hospital admissions at lags 0–2, 0–14, and 0–25. The effects of temperature on all age groups were non-linear. For the effects of extreme hot temperature, the cumulative risks on hospitalizations at lag 0–25 were highest among the elderly, while the cumulative effects of extreme cold temperature were highest among those aged 5-60 years.

Figure 1. Graphical Risks relative to the function of lag for all, 0-4 years, 5-60 years and> 60 years.



All

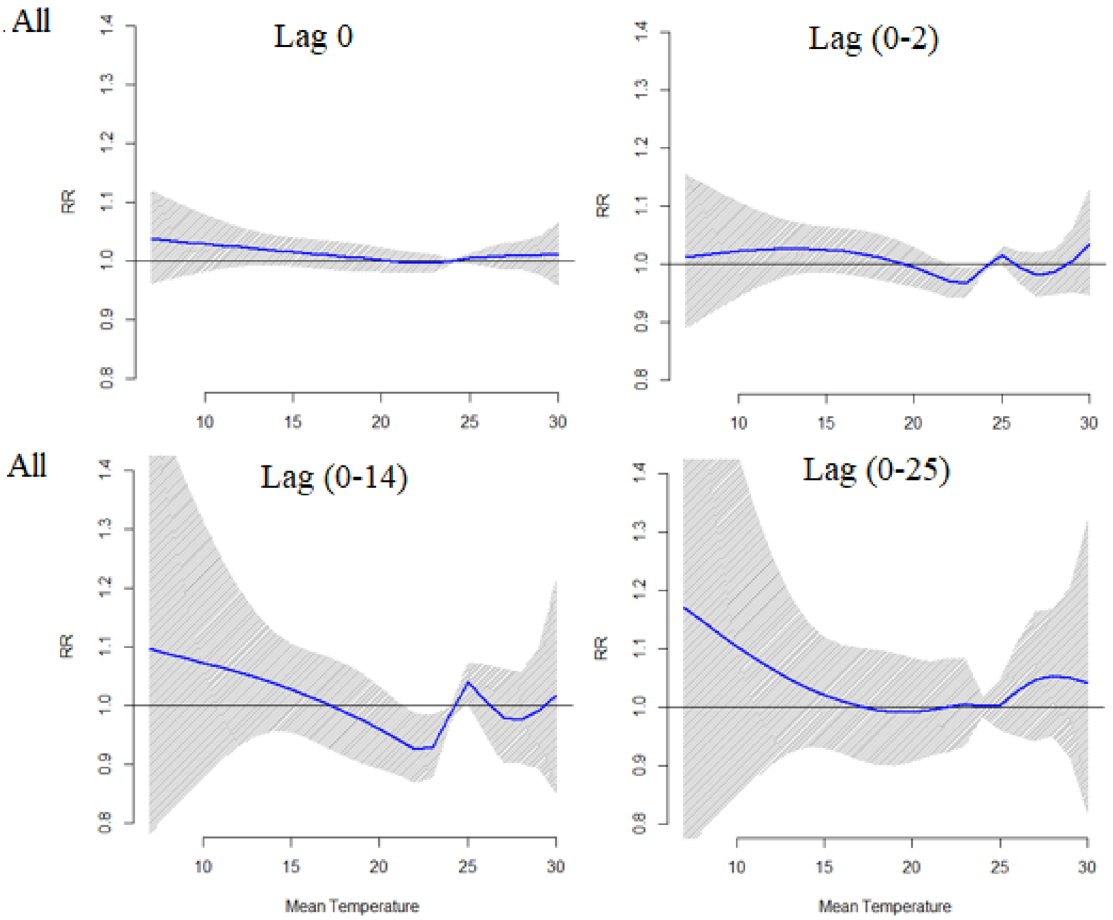
0-4

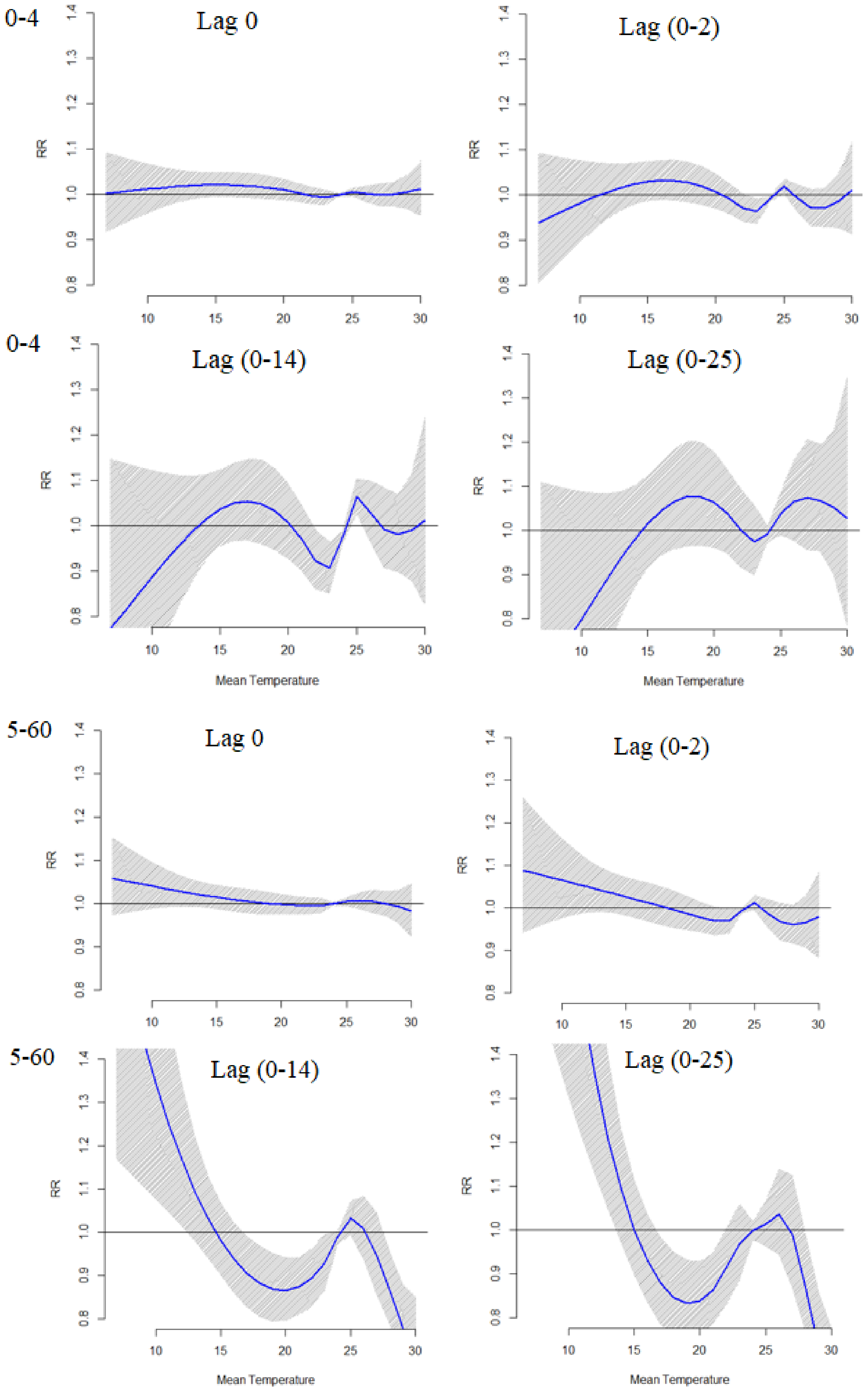
5-60

>60

Figures 2 and 3 show the hot and cold effects on age-specific hospitalizations along the lags. Heat effects increased at long lag days for all sub-groups except for those aged 5–60 years old and lasted longer in those older than 60 years. Cold effects were found to be more immediate.

Figure 2. The estimated cold freedom natural cubic spline, temperature (17.30°C)). The hot effect (right) was estimated by 99th percentile of temperature (30.07°C) relative to 75th percentile of temperature (32.59°C). The green lines are mean relative risks, and purple regions are 95% confidence intervals. Risks relative to the function of lag for all, 0-4 years, 5-60 years and> 60 years.




0-4
Lag 0
Lag (0-2)
0-4
Lag (0-14)
Lag (0-25)
5-60
Lag 0
Lag (0-2)
5-60
Lag (0-14)
Lag (0-25)
RR
0.8
0.9
1.0
1.1
1.2
1.3
1.4
10
15
20
25
30
Mean Temperature

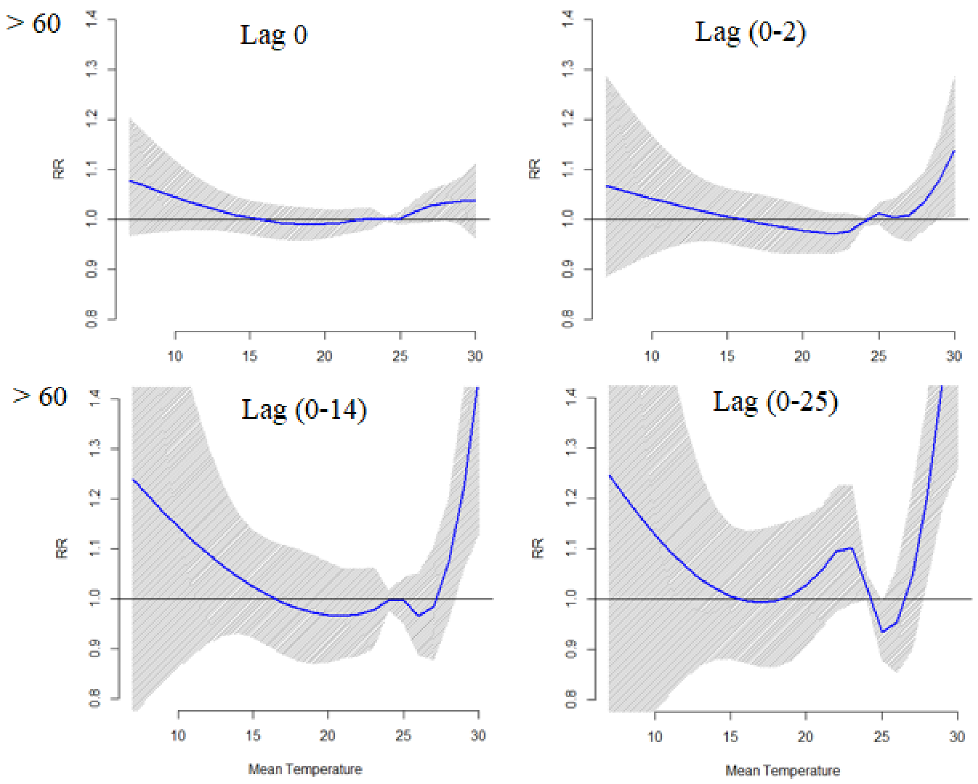
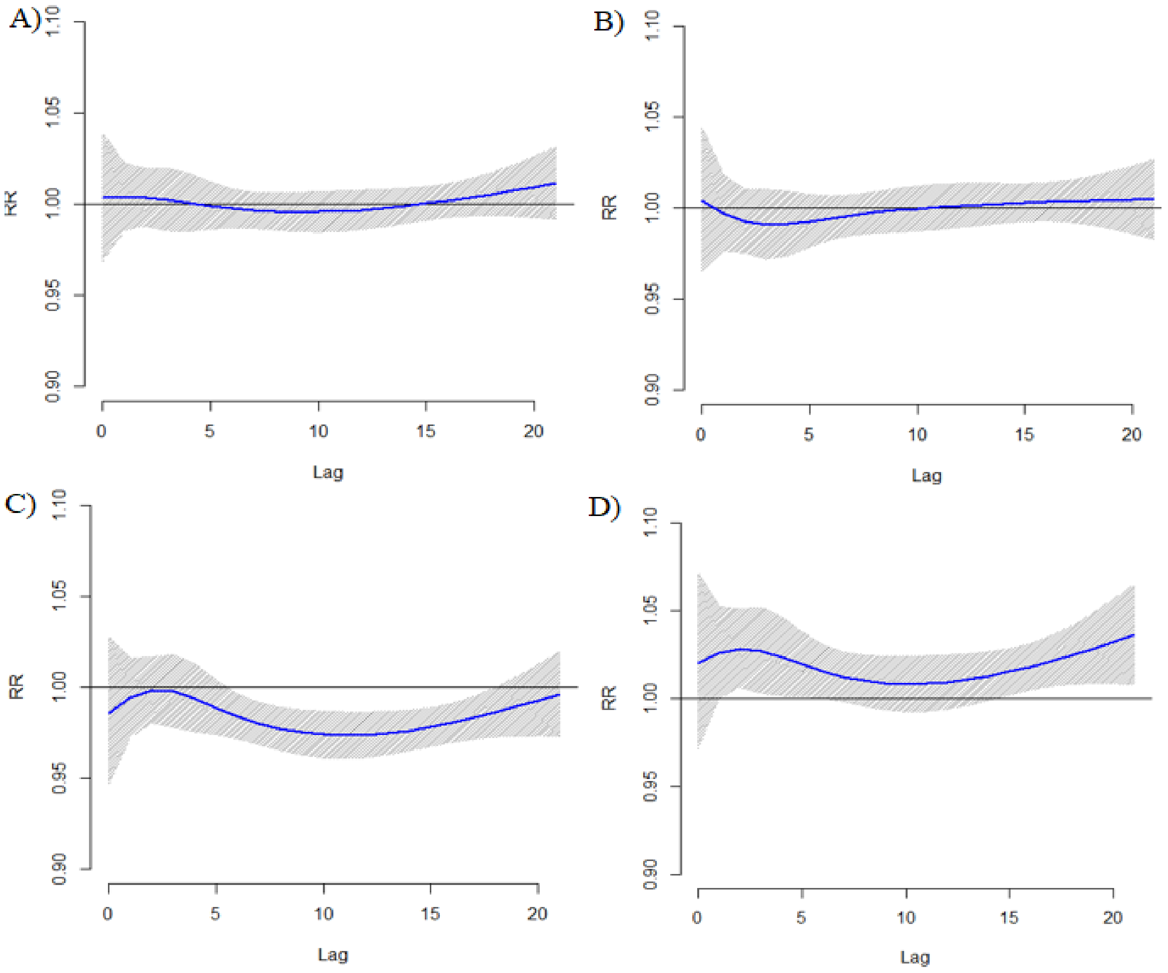


Figure 3. The estimated cold and hot effects of mean temperature morbity along the lag days, using 4 degrees of freedom natural cubic spline for lag. The cold effect (left) was estimated by 1st percentile of temperature (18.85°C) relative to 25th percentile of temperature (17.30°C)). Risks relative to the function of lag for A) all, B) 0-4 years, C) 5-60 years and D) > 60 years.



The cumulative hot and cold effects on age-specific respiratory hospitalizations along the lags were presented in Table 2 and Table 3. Both high and low temperatures had no statistically significant association with increased hospitalizations in all age groups at lag 0. Heat had a greater impact on the elderly, whereas those aged 5-60 years were more sensitive to cold temperatures. The highest cumulative risk of heat effects was observed among those older than 65 years at lag 0–25 (RR 1.509, 95% CI: 1.209-1.883). The highest risk of cold effect on respiratory hospitalizations was found in those aged 5- 60 years at lag 0–25 (RR 1.482, 95% CI: 1.231-1.785) (Figure 4).

Table 2. The cumulative relative risks (RR) of hot effects on age-specific hospital admissions for respiratory diseases.

Age	**Lag 0**	**Lag 0-2**	**Lag 0-14**	**Lag0-25**
All	1.003 (0.969-1.038)	1.010 (0.952-1.071)	0.982 (0.873-1.105)	1.021 (0.871- 1.197)
0-4	1.003 0.964 1.044	0.993 0.929 1.060	0.958 0.839 1.099	0.986 0.823 1.182
5-60	0.985 0.9451.027	0.978 0.913 1.047	**0.772 0.674 0.885**	**0.702 0.584 0.845**
>60	1.020 0.971 1.071	1.076 0.992 1.167	**1.268 1.076 1.494**	**1.509 1.2091 1.883**

The bold-faced data means statistically significant ($p < 0.05$)

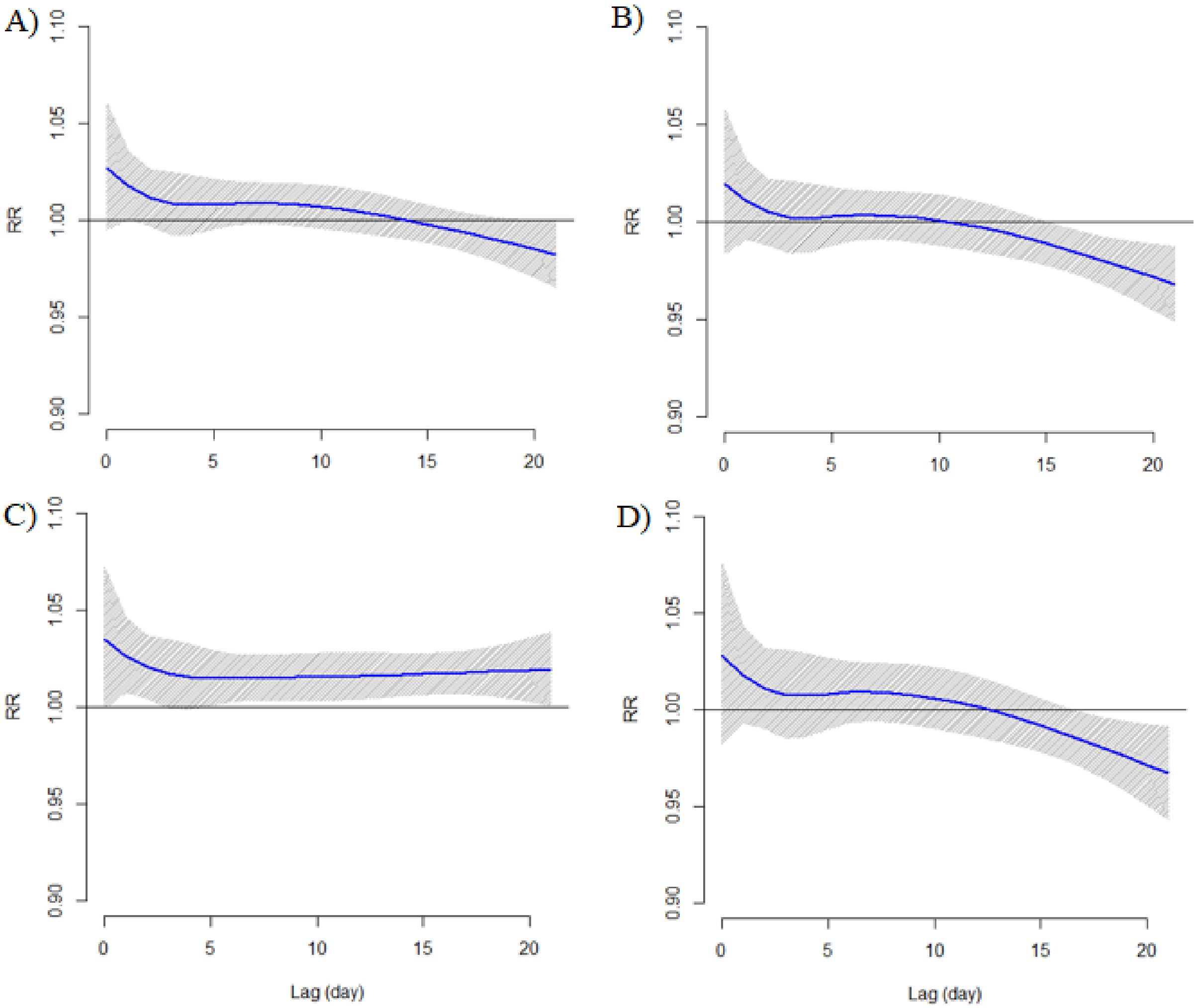
We varied the df for time (range 6-12 per year) to investigate the influence of seasonality, and found the results scarcely varied (data not shown). We altered the maximum lag days from 14-30 days, and the temperature effects were similar (data not shown). Additionally, the df for temperature and lags from 3 to 6 were changed, which also gave similar estimated effects.

Table 3. The cumulative relative risks of cold effects on age-specific hospital admissions for respiratory diseases.

Age	**Lag 0**	**Lag 0-2**	**Lag 0-14**	**Lag 0-25**
All	1.027 0.994 1.060	**1.057 1.001 1.116**	1.141 1.000 1.301	1.065 0.898 1.263
0-4	1.019 0.983 1.057	1.035 0.973 1.102	1.037 0.888 1.210	0.891 0.729 1.088
5-60	1.034 0.998 1.072	**1.084 1.021 1.150**	**1.306 1.130 1.510**	**1.482 1.231 1.785**
>60	1.027 0.982 1.075	1.057 0.978 1.141	**1.124 0.933 1.355**	0.973 0.764 1.239

The bold-faced data means statistically significant ($p< 0.05$)

Figure 4. The estimated cold effects of maximum temperature (1st relative to 25th percentile) on age-specific morbidities along the lags: A) all, B) 0-4 years, C) 5-60 years and D) > 60 years.



Discussion

This study examined the effects of temperature on respiratory hospital admissions by age groups in Campo Grande city, Brazil, during 2008-2014. We found that the temperature-morbidity relationship was non-linear for respiratory disease in all age groups. Although we did not observe immediate temperature effects on respiratory hospitalization, lag effects of both high and low temperatures were apparent. The elderly was found to be at higher risk during extreme hot days, whereas those aged 5-60 years were more sensitive to cold temperatures.

Previous studies have observed acute temperature effects on mortality (Braga et al. 2002; Guo et al. 2011; Yang et al. 2019) and morbity (Braga et al. 2002; Bai et al. 2014). The hot temperatures had short-term effects on mortality and morbidity (Yang et al. 2019) whereas the cold effect were normally delayed and lasted several days (Anderson and Bell 2009). In this analysis, we found acute cold effects (lag 0-2) on respiratory diseases and this may be in part because people in the city of Campo Grande with tropical weather patterns might not used to cold weather. Studies in Europe and USA have confirmed that cold temperatures tend to have greater impacts on mortality in warmer cities than in cold cities (Han et al. 2017).

Besides that the relationships between temperature and mortality have been examined in different parts of the world, such as USA, Europe and Australia (Yu et al. 2012; Yu et al. 2011; Curriero et al. 2002; Baccini et al. 2008; Rocklöv and Forsberg 2008), but there is little evidence in Brazil. Studies showed that effects of temperature on morbity/mortality varied by population and region (Rocklöv and Forsberg 2008; El-Zein et al. 2004; Revich and

Shaposhnikov 2008; Yu et al. 2011). In this study, both extreme cold and high temperatures had significant effects on age-specific respiratory hospital admission. A recent study has showed that cities with median or lower income (e.g., Bangkok, Mexico City, São Paulo, Delhi, Santiago, and Cape Town) are at higher risks of temperature-related mortality (Guo et al. 2017).

The variation of human responses to climate changes appears to be directly associated to questions of individual and collective vulnerability. Variables such as age, health profile, physiological resilience and social-economic status directly contribute to the human responses to climate variables. Factors which increase vulnerability include population growth, poverty and environmental degradation, which affect especially children, with an increase in respiratory and diarrheic diseases resulting from settlement of people in frequently inadequate locations (Barbieri 2015).

Atmospheric conditions may influence the transport of micro-organisms, as well as pollutants originating in fixed and mobile sources, and the production of pollen (Basu 2009). Effects of climate changes may be aggravated, depending on the physical and chemical characteristics of the pollutants and climatic conditions such as temperature, humidity and precipitation. These characteristics define the time period during which pollutants remain in the atmosphere, and they can be transported long distances in favorable conditions such as high temperatures and low humidity. These pollutants associated with climatic conditions can affect the health of populations far from the pollution generating sources.

The alterations in temperature, humidity and rainfall may increase the effects of respiratory diseases, as well as alter exposition to atmospheric pollutants. Given the evidence of the relation between health effects due to climatic variations and the levels of atmospheric pollution, such as episodes of thermal inversion, increases in pollution levels and an increase in respiratory problems, it seems inevitable that long-term climate changes will affect human health at a global level.

This study has two major strengths. Firstly, this study investigated the effects of temperature on respiratory morbidity by age group using an advanced statistical approach (DLNM) in Campo Grande city, Brazil. The advanced statistical approach can flexibly examine effects of temperature on morbity. For example, it can smooth temperature and lag at the same time. Secondly, we used ten years' data which had high quality (no missing data for mortality). We also adjusted for a range of confounders including relative humidity and air pollutants. However, some limitations of the study should be noted. First, this is an ecological study in which exposure misclassification might occur as detailed spatial information was unavailable in this study. In addition, with this study design it was not possible to control other time-varying confounding variables such as intake of alcohol, smoking rates and use of medications.

CONCLUSIONS

This study provides useful data for policy managers' decisions to better manage the health impacts of hot and cold temperatures. This study examined the effects of temperature on hospital admissions for respiratory diseases by age group in the city of Campo Grande, Brazil. The relationship between temperature and respiratory morbidity by age group was non-linear. Both hot and cold temperatures were associated with increased risk of respiratory morbidity. Both hot and cold effects can last longer. Heat-related risk in older people (> 60 years) was higher than those in other age groups. These results demonstrate that extreme temperatures can influence the health of priority populations in Campo Grande city.

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