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Full Length Research Paper

Temperature, hospital admissions in Campo Grande, MS, Brazil: A time-series analysis

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The association between temperature and morbidity has been examined mainly in Campo Grande, MS, Brazil. However, less evidence is available in developing countries, especially in Brazil. In this study, we examined the relationship between temperature and morbidity Campo Grande city, Brazil, during 2008–2014. A time series model was used to examine the effects of temperature on cause-specific morbidity (non-external and respiratory) and age-specific non-external mortality (0–4, 5–60, and > =65 years), while controlling for relative humidity, air pollution, day of the week, season and long-term trend. We used a distributed lag non-linear model to examine the delayed effects of temperature on morbidity up to 21 days. We found non-linear effects of temperature on all morbidity types and age groups. Both hot and cold temperatures resulted in immediate increase in all morbidity types and age groups. Generally, the hot effects on all morbidity types and age groups were short-term, while the cold effects lasted longer. The relative risk of non-external morbidity associated with cold temperature with 25th percentile of temperature (20.0°C) was 1.30 (95% confidence interval (CI): 1.04, 1.34) for lags 0–21. The relative risk of non-external mortality associated with high temperature with 75th percentile of temperature (35.4°C) was 1.14 (95% CI: 1.04, 1.34) for lags 0–21. This study indicates that exposure to both hot and cold temperatures were related to increased mortality. Both cold and hot effects occurred immediately but cold effects lasted longer than hot effects. This study provides useful data for policy makers to better prepare local responses to manage the impact of hot and cold temperatures on population health.

Keywords: respiratory diseases, temperatures, climate change, global change, environmental health surveillance; predictive models, Hospital admissions, Morbidity, Vulnerability

INTRODUCTION

Several studies around the world have documented a

relationship between increased ambient temperature and morbidity/mortality. Few studies have looked at morbidity, and there are none in Campo Grande, where temperature and humidity are generally mild, but where pollution levels tend to be higher than in other areas of

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the Brazil.

Periods of low and high ambient temperatures have been found associated with high mortality in a wide range of climates and countries (Martin et al., 2012; Guo et al., 2011; Huynen et al., 2001; Tawatsupa et al., 2012; Curriero et al., 2002; Armstrong et al., 2011). However, most previous studies have examined temperature effects only by community or country (Guo et al., 2011; Tawatsupa et al., 2012; Anderson and Bell, 2009), although some evidence of adaptation to local climates is clear from studies within large countries (Curriero et al., 2002; Anderson and Bell, 2009) and the limited number of international studies, (Analitis et al., 2008; McMichael et al., 2008; Baccini et al., 2008) there are no studies with a wide range of globally diverse communities and climates. The different analytic approaches adopted in studies on single countries or regions, in particular considering different lag periods, makes it difficult to assess how associations differ across climates and societies. In addition, some studies examined the effects of only high temperatures or only cold temperatures, which makes it difficult to define whether people have the ability to adapt to their local climates. (Basu and Samet, 2002; Basu, 2009) considering the global ambient temperature changes that are expected in the context of climate change, an international perspective on the temperature health effects carries with it important public health implications.

In Mato Grosso do Sul, the intense biomass burning covers an area of 357,124.96 km² observed through remote sensing. Studies conducted in the region during the rainy season, when natural emissions are predominant, show that the ozone concentration is of the order of 10 to 15 µg.m⁻³. In the dry season, due to emissions from burning, the concentration triples (Souza et al., 2010). Most biogenic particles lie in coarse fraction, with a diameter greater than 2 µm, and has the constitution especially fungi, spores, bacteria and leaf fragments in a wide variety of particles.

The closer the location of exposure to fire outbreaks, usually the greater is its effect on health. But the direction and the intensity of air currents have much influence on the dispersion of air pollutants and on the areas affected by the fire plume arising from the fire. If the prevailing winds direct to densely populated areas, a greater number of people will be subject to the effects of contaminants.

The aim of the study is to provide subsidies to the impact of temperature in the city of Campo Grande MS on respiratory morbidity.

METHODS

Data Collection

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 km²), and an estimated population of 850,000 inhabitants. Souza et al, 2009; using the Koppen's method, 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, with hot summer and well distributed rainfall, average relative humidity is 72.8%. Souza and Granja (1997) found prevailing winds in East Campo Grande - MS, occurring the North in months from January to December, with annual values resulted in 24% of East, 19.8% of North and 12, 2% of Northeast, and the lulls represented 12% with an average speed of 3.1 m / s, and average monthly rainfall in 122,4mm and annual average 1469 mm.

For the correlation of weather data with the aggravation of respiratory illnesses, hospitalization data were collected from the health agencies of the SUS (Unified Health System) Department of Informatics (DATASUL).

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 1st, 2008 and December 31st, 2014, the diseases investigated were coded according to the International Classification of Diseases (CID) 10th Revision (CID10 J10 to J18).

Information about daily levels of ozone (O₃) were obtained from the Institute of Physics of UFMS. The Ozone Analyzer, used for the measurements has as working principle the absorption of ultraviolet radiation by the ozone molecule. These measurements are performed continuously 24 hours a day; every 15 minutes are provided values of the ozone concentration. The analyzer is installed near Campo Grande, away from local sources.

In this study was performed a descriptive analysis of the variables and, subsequently, the hypotheses were tested using Multiple Regression Models. The response variable of a Poisson regression must follow a Poisson

Table 1. Descriptive analysis of respiratory hospital admission and temperature °C in Campo Grande, Brazil during 2004-2010.

	Average	Standard	Minimum	1 ^o quartil	Median	3 ^o quartil	Maximum
Total	11	3	5	8	10	13	19
0 - 4 years	5	2	2	4	5	6	11
5 - 60 years	3	1	1	2	2	3	7
>60 years	3	1	0	2	3	4	5
Mean Temperature	22,2	3,7	11	20	23,3	24,9	27,8
Max Temperature	28,6	4,2	15,2	25,8	30,1	31,7	35,4
min Temperature	22,2	3,7	11	20,0	23,3	24,9	27,8

distribution where the average of the response variable must be equal to the variance. When working with experimental data, it is not always the case, a super dispersion (greater than the mean variance) or a sub-case dispersion (variance is less than the average) may occur (Baccini et al., 2008; Hajat et al., 2006).

Statistical models

In this study, we used a Poisson regression model combined with a distributed lag non-linear model (DLNM) to examine the impact of temperature on mortality (Armstrong, 2006; Gasparrini et al., 2010). We used a quasi-Poisson function that allows for over-dispersion in daily deaths. We controlled for PM₁₀ (moving average of lags 0–7), O₃ (moving average of lags 0–7) and relative humidity (moving average of lags 0–7) using a natural cubic spline with 3 degrees of freedom (df), as these variables are potential confounders of the association between temperature and mortality (Gouveia and Fletcher, 2000; Bernard et al., 2001; Buadong et al., 2009). We controlled for day of the week as a category variable. We controlled for season and long-term trend using a natural cubic spline with 7 df per year for time, as the estimated effects of temperature were then stabilized.

Many studies have shown that the extreme temperature can not only affect current day's morbidity but also influence the several following days' morbidity (lag effect) (Guo et al., 2011; Braga et al., 2002; Zanobetti, 2000). Also, the relationship between temperature and morbidity is non-linear (Gouveia and Fletcher, 2000). Therefore, we used a DLNM to examine the non-linear and delayed effects of temperature on cause-specific and age-specific mortality. 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. The DLNM can show the relationship between temperature and morbidity at each temperature point and lag. The DLNM can calculate cumulative effect in the existence of delayed contributions (de Souza et al., 2014; Gasparrini et al., 2010).

We used a "natural cubic spline-natural cubic spline"

DLNM to examine the non-linear temperature effect using a 5 df natural cubic spline and the lagged effect using a 4 df natural cubic spline. A maximum lag of 21 days was used to model the effect of temperature on morbidity, because previous studies suggest that the effects of cold temperature last about ten days and the effects of high temperature are usually acute and short term (Guo et al., 2011; Braga et al., 2002; Tong et al., 2010). We placed spline knots at equal spaces in the temperature range, and placed spline knots at equal intervals in the log scale of lags using the default setting of DLNM. The median value of temperature was used as the reference value to calculate the relative risks.

RESULTS

Temperature has been recognized as a physical agent able to induce health effects (Kalkstein and Greene, 1997; McGeehin and Mirabelli, 2001; Houghton et al., 2009). The rapid buildup of greenhouse gases is expected to increase both mean temperature and temperature variability around the world (McCarthy et al., 2001). This has added urgency to the need to better understand the direct effects of such changes on daily morbidity/death rates, and to better understand the modifiers of those effects. One issue that has been extensively explored in this field is the shape of the relationship between temperature and morbidity. We have focused our attention on exploring the lag structure between temperature and daily morbidity using a systematic approach to look at the delayed effects of weather on morbidity up to 7 days afterwards.

During the study period (January 1, 2008 to December 31, 2014) the number of admissions for respiratory diseases were 4.486.

The average counts of daily admissions for respiratory diseases were: total admissions for respiratory diseases, 0 - 4 years, 5 - 60 years, and >60 years and temperature °C (Table 1).

Figure 1 shows the time series of respiratory hospital admission and mean temperature, with higher hospital admission in 2008 to 2014.

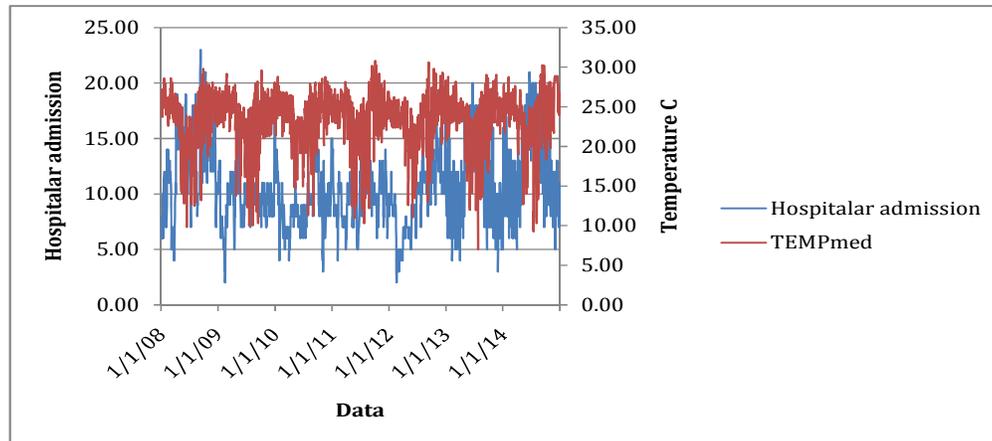


Figure 1. Time series of respiratory hospital admissions and mean temperature (°C) during 2008-2014

Table 2. The cumulative effects of cold temperature on cause-specific morbidity and age-specific non-external morbidity, with 1st quartil of temperature (20.0°C).

	Relative risk (95% CI)				
	Non-external	All years	0-4 years	5-65 years	>65 years
lag 0	1.06(1.03,1.10)	1.07(1.02,1.13)	1.04(0.97,1.11)	1.08(1.01,1.16)	1.09(0.92,1.30)
lag 0-1	1.10(1.05,1.16)	1.11(1.04,1.19)	1.06(0.96,1.17)	1.12(1.02,1.23)	1.12(0.96,1.32)
Lag 0-2	1.12(1.06,1.18)	1.12(1.05,1.21)	1.08(0.99,1.21)	1.14(1.03,1.27)	1.13(0.99,1.31)
Lag 0-3	1.13(1.08,1.20)	1.12(1.06,1.21)	1.11(1.00,1.21)	1.15(1.03,1.28)	1.15(0.95,1.32)
Lag 0-7	1.13(1.07,1.23)	1.11(1.03,1.19)	1.16(1.05,1.26)	1.17(1.03,1.33)	1.27(1.04,1.52)
Lag 0-13	1.18(1.11,1.31)	1.13(0.99,1.22)	1.22(1.05,1.43)	1.24(1.07,1.46)	1.42(1.16,1.77)
Lag 0-21	1.30(1.14,1.41)	1.20(1.02,1.40)	1.34(1.12,1.69)	1.31(1.01,1.63)	1.623(1.28,2.32)

Table 3. The cumulative effects of high temperature on cause-specific mortality and age-specific non-external mortality, with 75th percentile of temperature (35.4°C).

	Relative risk (95% CI)				
	Non-external	All years	0-4 years	5-65 years	>65 years
lag 0	1.10(1.06,1.17)	1.13(1.06,1.19)	1.12(1.05,1.23)	1.09(1.03,1.20)	1.17(1.02,1.43)
lag 0-1	1.17(1.11,1.27)	1.17(1.09,1.30)	1.18(1.07,1.31)	1.14(1.02,1.30)	1.29(1.08,1.52)
Lag 0-2	1.21(1.14,1.26)	1.20(1.12,1.32)	1.20(1.09,1.34)	1.18(1.06,1.29)	1.30(1.09,1.55)
Lag 0-3	1.21(1.16,1.29)	1.19(1.12,1.29)	1.20(1.08,1.35)	1.19(1.06,1.35)	1.31(1.09,1.59)
Lag 0-7	1.17(1.09,1.26)	1.13(1.04,1.22)	1.18(1.03,1.36)	1.24(1.75,1.40)	1.25(1.00,1.56)
Lag 0-13	1.16(1.07,1.27)	1.12(0.98,1.28)	1.16(0.96,1.39)	1.29(1.09,1.52)	1.06(0.92,1.40)
Lag 0-21	1.14(1.04,1.34)	1.06(0.936,1.29)	1.09(0.94,1.42)	1.35(1.09,1.72)	0.93(0.67,1.23)

Table 2 and Figure 2 show the relative risks of hospital admissions at 75% percentile of ozone distribution compared with 25% percentile along the lag days. Results show that the effects on hospitalizations were delayed by two days, and lasted for four days.

We calculated the cumulative effects of cold

temperature on cause-specific morbidity and age-specific non-external mortality along the lags, with 25th percentile of temperature (20.0°C) (Table 2). The cold temperature was significantly associated with the risk of all mortality types and age groups, except for respiratory mortality.

We calculated the cumulative effects of high

temperature on cause-specific morbidity and age-specific non-external morbidity along the lags, with 75th percentile of temperature (35.4°C) (Table 3). For the short lags (e.g., lag 0 to lag 0–3), the high temperature was significantly associated with the risk of all morbidity types and age groups.

DISCUSSION

In this study, we have analyzed the associations between daily maximum temperature and hospital admissions in Campo Grande, Brazil during 2008–2014. It appears that elevated temperatures affect morbidity to a greater degree than do low temperatures. High temperatures were associated with increases of total and hospitalizations for respiratory diseases. Lag effects of both high and low temperatures were cause-specific. Acute temperature effects were observed with respiratory, and hospitalizations for non-external and infectious diseases. We also observed some signs of increased vulnerability to high temperatures among those ≥ 65 years of age. This study is, to our best knowledge, the first to examine temperature-related morbidity and vulnerable subpopulations in Campo Grande of Brazil.

Others have suggested that heat exposure tends to be more troublesome in cold regions, whereas warm regions may suffer more from cold weather (Yang et al., 2013). Our findings are consistent with this since heat had a greater impact on human health than cold, and Campo Grande experiences mild summer climates and extreme cold winter temperatures. It may be that people living in relatively cold regions have low awareness and limited coping resources (such as air-conditioning) to deal with the heat.

Others have reported immediate effects of ambient temperatures on total and cause-specific mortalities (Guo et al., 2012; Huang et al., 2014; Tian et al., 2012) and measures of morbidity (Chan et al., 2013; Wichmann et al., 2011; Wichmann et al., 2013; Zanobetti et al., 2013). In our analysis, we found both hot and cold effects with a range of lag periods. Lin et al. (2009) found that the greatest number of hospital admissions for respiratory diseases was 0–1 days after elevated temperatures.

Apart from short hot effects, delayed and longer lasting heat effects (lags 0–4) were observed with the increase of total hospitalizations disease admissions in this study. Most previous studies focused on short-term heat effects on cause-specific emergency department visits and hospital admissions such as total cardiovascular diseases (Ren and Tong, 2006; Michelozzi et al., 2009), total respiratory diseases (Lin et al., 2009; Lavigne et al., 2014), acute myocardial infarction (Wichmann et al., 2013) and stroke (Dawson et al., 2008; Ohshige et al., 2006). However, a few confirmed the associations with total emergency room visits or total non-external hospitalizations. For instance, a study in UK found no

relation between total emergency room visits and heat when using short-term temperatures (three-day moving average temperature) (Kovats et al., 2004).

Seasonal climate fluctuations have an effect on the dynamics of vector diseases, such as a greater rate of dengue in the summer and malaria in the Amazon during the dry period. Extreme events introduce considerable fluctuations, which can affect the dynamics of waterborne diseases, such as leptospirosis, viral hepatitis diseases, diarrhoeic diseases, etc. These diseases can become more prevalent with flooding or droughts that affect the quality of and access to water. Respiratory diseases are also influenced by burning and the effects of thermal inversions that concentration pollution, directly impacting the quality of the air, principally in urban areas. Additionally, malnutrition can occur due to agricultural losses, especially in the case of subsistence farming, due to frosts, strong winds, droughts or abrupt flooding.

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 conditions directly contribute to the human responses to climate variables. Some studies also mention that some factors which increase vulnerability to climate problem are a combination of populational growth, poverty and environmental degradation, especially in children, with an increase in respiratory and diarrhoeic diseases resulting from settlement of people in frequently inadequate locations (McMichael, 2003; Intergovernmental Panel on Climate Change, 2001).

Atmospheric conditions may influence the transport of micro-organisms, as well as pollutants originating in fixed and mobile sources, and the production of pollen (Moreno, 2006). The effects of climate changes may be potentialized, 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 favourable 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 can increase the effects of respiratory diseases, as well as alter exposition to atmospheric pollutants. Given the evidence of the relation between some effects on health 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.

The elderly are more vulnerable in areas where air pollution is more intense. This, together with high ambient temperatures, causes stress and loss of physiological resilience. Social conditions, such as housing, food and

access to health services are factors that increase the vulnerability of those exposed to episodes of climate changes which, when added to exposure to atmospheric pollutants, may cause synergetic effects and worsen health conditions. In areas with or without limited urban infra-structure, principally in developing countries, all these factors fall on the most vulnerable individuals and, consequently, the poorest, pressuring the public health infrastructure, overwhelming services and increasing health spending.

Cardiovascular diseases are well-known to be sensitive to extreme temperatures (Basu, 2008). However, we found neither hot nor cold effects for this category of diseases. A review on recent temperature-morbidity studies concluded that sensitivity of cardiovascular diseases to temperatures varies by subtypes (Ye et al., 2012). Chronic and acute cardiovascular diseases were found to have opposite relationships to temperature increases in some studies (Green et al., 2009; Koken et al., 2003). The authors suggested that those with chronic long-standing conditions might avoid outdoor exposures during unpleasant weather, resulting in a null or negative correlation with temperature. Findings in our survey may also support this conclusion (Bai et al., 2013). In Campo Grande, we found that residents with chronic diseases were more likely to perceive the risk on health of excessive heat and were more likely to alter their behaviors during hot summer days (e.g. drinking more fluids, staying indoors and avoiding the sun).

Many studies have examined the relationship between temperature and mortality in Australia, Europe, and USA (Yu et al., 2012; Yu et al., 2011; Baccini et al., 2008; Rocklöv and Forsberg, 2008)(Chan et al., 2013; Wichmann et al., 2011; Wichmann et al., 2013; Zanobetti et al., 2013; Lin et al., 2009), but few are from Brazil. Studies showed that effects of temperature on mortality varied by population and region (Rocklöv and Forsberg, 2008; Revich and Shaposhnikov, 2008). Studies showed that cities with median or lower income (e.g., Bangkok, Mexico City, São Paulo, Delhi, Santiago, and Cape Town) had significant hot and cold effects on non-external mortality (Guo et al., 2011).

CONCLUSIONS

This study examined the effects of temperature on cause-specific and age-specific morbidity in Campo Grande city, Brazil. The relationships between temperature and cause-specific and age-specific morbidity were non-linear. Both cold and hot temperatures were associated with increased risk in morbidity. Both cold and hot effects occurred immediately. Cold effects lasted longer than hot effects. Cold related morbidity risk in oldest people (children 0-4 years; aged ≥ 65 years) was higher than

other age groups. These results demonstrate that temperature is an important environmental hazard in Campo Grande city.

REFERENCES

- Analitis A, Katsouyanni K, Biggeri A, et al (2008). Effects of cold weather on mortality: results from 15 European cities within the PHeWe project. *Am. J. Epidemiol.* 168:1397–1408.
- Anderson BG, Bell ML (2009). Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiol.* 20: 205–213.
- Armstrong B (2006). Models for the relationship between ambient temperature and daily mortality. *Epidemiol.* 17:624–631.
- Armstrong BG, Chalabi Z, Fenn B, et al (2011). Association of mortality with high temperatures in a temperate climate: England and Wales. *J. Epidemiol. Community Health.* 65:340–345.
- Baccini M, Biggeri A, Accetta G, et al (2008). Heat effects on mortality in 15 European cities. *Epidemiol.* 19:711–19.
- Baccini M, Biggeri A, Accetta G, Kosatsky T, Katsouyanni K, Analitis A, Anderson HR, Bisanti L, D'Ippoliti D, Danova J, et al (2008). Heat effects on mortality in 15 European cities. *Epidemiol.* 19:711–719.
- Bai L, Cirendunzhu D, Pengcuociren D, Dawa D, Woodward A, Liu X, et al (2013). Rapid warming in Tibet, China: public perception, response and coping resources in urban Lhasa. *Environ. Health.* 12: 71.
- Basu R (2008). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. *Environ. Health.* 8: 40.
- Basu R (2009). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. *Environ. Health.* 8:1–13.
- Basu R, Samet JM (2002). Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiol. Rev.* 24:190–202.
- Bernard S, Samet J, Grambsch A, Ebi K, Romieu I (2001). The potential impacts of climate variability and change on air pollution-related health effects in the United States. *Environ Health Perspect.* 109:199.
- Braga A, Zanobetti A, Schwartz J (2002). The effect of weather on respiratory and cardiovascular deaths in 12 U.S. cities. *Environmental Health Perspective,* 110:859–863.
- Buadong D, Jinsaart W, Funatagawa I, Karita K, Yano E (2009). Association between PM10 and O3 levels and hospital visits for cardiovascular Disease in Bangkok, Thailand. *J. Epidemiol.* 19:182–188.
- Chan EY, Goggins WB, Yue JS, Lee P (2013). Hospital admissions as a function of temperature, other weather phenomena and pollution levels in an urban setting in Chin. *Bull World Health Organ.* 91: 576–584.
- Curriero Fc, Heiner KS, Samet JM, Zeger SI, Strug I, Patz JA (2002). Temperature and mortality in 11 cities of the eastern United States. *Am. J. Epidemiol.* 155:80–87.
- Dawson J, Weir C, Wright F, Bryden C, Aslanyan S, Lees K, et al (2008). Associations between meteorological variables and acute stroke hospital admissions in the west of Scotland. *Acta Neurol. Scand.* 117: 85–89.
- de Souza A, Guo Y, Pavão HG, Fernandes WA (2014). Effects of Air Pollution on Disease Respiratory: Structures Lag. *Health,* 6: 1333–1339. <http://dx.doi.org/10.4236/health.2014.612163>
- Gasparrini A, Armstrong B, Kenward M (2010). Distributed lag non-linear models. *Stat. Med.* 21:2224–2234.
- Gasparrini A, Armstrong B, Kenward MG (2010). Distributed lag non-linear models. *Stat. Med.* 29:2224–2234.
- Gouveia N, Fletcher T(2000). Time series analysis of air pollution and mortality: effects by cause, age and socioeconomic status. *J. Epidemiol. Community Health,* 54:750–755.
- Green RS, Basu R, Malig B, Broadwin R, Kim JJ, Ostro B (2009). The effect of temperature on hospital admissions in nine California counties. *Int. J. Public Health.* 55: 113–121.

- Guo Y, Barnett AG, Pan X, Yu W, Tong S (2011). The impact of temperature on mortality in Tianjin, China: a case-crossover design with a distributed lag nonlinear model. *Environmental health perspectives* 119: 1719–1725.
- Guo Y, Punnasiri K, Tong S (2012). Effects of temperature on mortality in Chiang Mai City, Thailand: a time series study. *Environ. Health*. 11: 36.
- Hajat S, *et al* (2006). Impact of high temperatures on mortality: is there an added heat wave effect? *Epidemiol.* 17: 632–638.
- Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Xiaosu D eds (2001). *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge University Press, Cambridge and New York, pp. 739-768.
- Huang J, Wang J, Yu W (2014). The lag effects and vulnerabilities of temperature effects on cardiovascular disease mortality in a subtropical climate zone in China. *Int. J. Environ. Res. Public Health*. 11: 3982–3994.
- Huynen MM, Martens P, Schram D, Weijnenberg MP, Kunst AE (2001). The impact of heat waves and cold spells on mortality rates in the Dutch population. *Environ. Health Perspect.* 109:463–470.
- Intergovernmental Panel on Climate Change (2001). *The Science of Climate Change – The Scientific Basis – Contribution of Working Group 1 to the IPCC. The assessment report*. Cambridge Univ.
- Kalkstein LS, Greene JS (1997). An evaluation of climate/mortality relationship in large U.S. cities and the possible impacts of a climate change. *Environ. Health Perspect.* 105:84–93.
- Koken PJ, Piver WT, Ye F, Elixhauser A, Olsen LM, Portier CJ (2003). Temperature, air pollution, and hospitalization for cardiovascular diseases among elderly people in Denver. *Environ. Health Perspect.* 111: 1312–1317.
- Kovats RS, Hajat S, Wilkinson P (2004). Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. *Occup. Environ. Med.* 61: 893–898.
- Lavigne E, Gasparrini A, Wang X, Chen H, Yagouti A, Fleury MD, Cakmak S (2014). Extreme ambient temperatures and cardiorespiratory emergency room visits: assessing risk by comorbid health conditions in a time series study. *Environ. Health*. 3(13):5.
- Lin S, Luo M, Walker RJ, Liu X, Hwang SA, Chinery R (2009). Extreme high temperatures and hospital admissions for respiratory and cardiovascular diseases. *Epidemiol.* 20: 738–746
- Martin SL, Cakmak S, Hebborn CA, Avramescu ML, Tremblay N (2012). Climate change and future temperature-related mortality in 15 Canadian cities. *Int. J. Biometeorol.* 56:605–619.
- McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, eds (2001). *Climate Change 2001: Impacts, Adaptation and Vulnerability Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge:Cambridge University Press.
- McGeehin MA, Mirabelli M (2001). The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. *Environ. Health Perspect.* 109(suppl 2):185–189.
- McMichael AJ (2003). Global climate change and health: an old story writ large. In: McMichael AJ, Campbell-Lendrum DH, Corvalan CF, Ebi KL, Githenko A, Scheraga JD, *et al*, editors. *Climate change and human health. Risks and responses*. Geneva: WHO. pp. 1-17.
- McMichael AJ, Wilkinson P, Kovats RS, *et al* (2008). international study of temperature, heat and urban mortality: the 'ISOTHURM' project. *Int. J. Epidemiol.* 37:1121–1131
- Michelozzi P, Accetta G, De Sario M, D'Ippoliti D, Marino C, Baccini M, *et al* (2009). High temperature and hospitalizations for cardiovascular and respiratory causes in 12 European cities. *Am. J. Respir. Crit. Care Med.* 179: 383–389.
- Moreno AR (2006). Climate change and human health in Latin America: drives, effects and policies. *Environmental Change*. 6:157-164.
- Ohshige K, Hori Y, Tochikubo O, Sugiyama M (2006). Influence of weather on emergency transport events coded as stroke: population-based study in Japan. *Int. J. Biometeorol.* 50: 305–311.
- Ren C, Tong S (2006). Temperature modifies the health effects of particulate matter in Brisbane, Australia. *Int. J. Biometeorol.* 51: 87–96.
- Revich B, Shaposhnikov D (2008). Temperature-induced excess mortality in Moscow, Russia. *Int. J. Biometeorol.* 52:367–374.
- Rocklöv J, Forsberg B (2008). The effect of temperature on mortality in Stockholm 1998–2003: A study of lag structures and heatwave effects. *Scandinavian j. public health*, 36:516–523.
- Souza A, Granja SC (1997). Estimativa dos parâmetros "C" e "K" do modelo de Weibull e da direção dos ventos para Campo Grande e Dourados, MS, Brasil. *Revista Brasileira de Agrometeorologia, Santa Maria*. 5(1):109-114.
- Souza A, Pavão H, Lastoria G, Gabas SG, Paranhos Filho AC, Cavazzana GH (2010). Hospitalizações por causas respiratórias associadas à poluição atmosférica em Campo Grande, MS. *REVISTA DE BIOCÊNCIAS-UNITAU*. 16: 43-49.
- Tawatsupa B, Dear K, Kjellstrom T, Sleight A (2012). The association between temperature and mortality in tropical middle income Thailand from 1999 to 2008. *Int. J. Biometeorol.* 58:1–13.
- Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge:Cambridge University Press.
- Tian Z, Li S, Zhang J, Jaakkola JJ, Guo Y (2012). Ambient temperature and coronary heart disease mortality in Beijing, China: a time series study. *Environ. Health*, 11: 56.
- Tong SL, Ren C, Becker N (2010). Excess deaths during the 2004 heatwave in Brisbane, Australia. *Int. J. Biometeorol.* 54:393–400.
- Wichmann J, Andersen Z, Ketzler M, Ellermann T, Loft S (2011). Apparent temperature and cause-specific emergency hospital admissions in Greater Copenhagen, Denmark. *PLoS ONE*. 6: e22904
- Wichmann J, Rosengren A, Sjöberg K, Barregard L, Sallsten G (2013). Association between ambient temperature and acute myocardial infarction hospitalisations in Gothenburg, Sweden: 1985–2010. *PLoS ONE*, 8: e62059.
- Yang J, Liu HZ, Ou CQ, Lin GZ, Zhou Q, Shen GC, *et al* (2013). Global climate change impact of diurnal temperature range on mortality in Guangzhou, China. *Environ. Pollut.* 175: 131–136.
- Ye X, Wolff R, Yu W, Vaneckova P, Pan X, Tong S (2012). Ambient temperature and morbidity: a review of epidemiological evidence. *Environ. Health Perspect.* 120, pp. 19–28.
- Yu W, Hu W, Mengersen K, Guo Y, Pan X, Connell D, Tong S (2011). Time course of temperature effects on cardiovascular mortality in Brisbane, Australia. *Heart*. 97:1089–1093.
- Yu W, Mengersen K, Wang X, Ye X, Guo Y, Pan X, Tong S (2012). Daily average temperature and mortality among the elderly: a meta-analysis and systematic review of epidemiological evidence. *Int. J. Biometeorol.* 56(4):80–87, in press.
- Zanobetti A (2000). Generalized additive distributed lag models: quantifying mortality displacement. *Biostatistic*. 1:279–292.
- Zanobetti A, O'Neill MS, Gronlund CJ, Schwartz JD (2013). Susceptibility to mortality in weather extremes: effect modification by personal and small-area characteristics. *Epidemiol.* 24: 809–819.