Brazil

Climate, air pollution and socioeconomic vulnerability: a research platform to implement policies to improve environmental health

Case study prepared by:

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Focus

Humans have adapted to a wide range of environmental conditions. We live in habitats with temperatures ranging from minus 68 degrees Celsius, in the Arctic region, to 45 degrees Celsius in desert environments. This capacity to adapt has marked our success as a species. However, this is now being challenged by rapid changes in the global climate.

Different countries have varying levels of vulnerability to climate change-induced risks. Socioeconomic contrasts, migration and demographic changes are occurring in populations all over the world. But there are also marked disparities in human vulnerability to climate alterations within countries. It is unclear whether this unevenness is due to temperature alone, or a combination of other factors such as air pollution, socioeconomics and the presence and increase of clinical conditions that increase people's vulnerability.

This study aims to uncover these disparities and measure differences in vulnerability in different populations. The research focuses on Brazil, which has a number of characteristics that favour large-scale studies into climate-induced health risks, as follows:

1. A large population;
2. Significant climate variability due to the size of the territory;
3. The availability of daily health data, including morbidity and mortality;
4. Extreme social and economic contrasts.

This case study explores the effects of climate abnormalities and the impact these have on population health in 1,800 Brazilian cities. The cities represent a wide range of geographic and climatic areas – from tropical rainforest to semi-arid zones in the northeastern states.

Method

Researchers analysed national data sets, spanning 15 years of certified daily hospital admissions (including mortality) for more than 1,800 Brazilian cities. The relationship between climate and health was then quantified using the health data and meteorological conditions for each city.

Statistical data analysis software (Quasi-Poisson regression) was applied to the data to examine city-specific estimates of climate impacts on health. This data was then aggregated at the regional and national levels using random-effect meta-analyses (which assumed that underlying effects followed a normal distribution). Stratified analyses (organising data into groups) were then performed by sex, age and cause (health factor/mortality). Meta-regression (to combine and contrast multiple subsets of the study) was then used to examine temporal changes in each region and the effects these changes had on human health. These approaches were demonstrated to be robust and reproducible, and more details can be obtained in the papers referenced in the full version of this manuscript.

Results

Temperature variability, socioeconomics and health

Results indicated that the adverse health effects of temperature and temperature variability were significantly influenced by socioeconomic indicators (e.g. literacy rates,

	Number of cities	Number of cases	Increased hospitalisation risk, % (95% CI)	p values for difference*
Literacy rate quartiles				
Q1 (lowest)	454	15344354	0·80 (0·70–0·89)	Ref
Q2	453	23313694	0·61 (0·55–0·67)	0·0018
Q3	453	29918657	0·57 (0·53–0·62)	<0·0001
Q4 (highest)	454	79382538	0·43 (0·40–0·46)	<0·0001
Urbanisation rate quartiles				
Q1 (lowest)	454	14195131	0·63 (0·55–0·71)	Ref
Q2	453	16761150	0·56 (0·50–0·63)	0·21
Q3	453	24471426	0·53 (0·48–0·58)	0·030
Q4 (highest)	454	92531536	0·49 (0·45–0·52)	0·0010
Average household income quartiles				
Q1 (lowest)	458	15021111	0·77 (0·67–0·86)	Ref
Q2	449	25296158	0·59 (0·53–0·65)	0·0019
Q3	456	30011571	0·52 (0·48–0·57)	<0·0001
Q4 (highest)	451	77630403	0·46 (0·43–0·49)	<0·0001
GDP per-capita quartiles				
Q1 (lowest)	454	15983538	0·69 (0·60–0·79)	Ref
Q2	453	27860410	0·59 (0·54–0·64)	0·060
Q3	453	37544498	0·53 (0·49–0·58)	0·0026
Q4 (highest)	454	66570797	0·45 (0·42–0·48)	<0·0001
GDP per-capita classifications				
Lower-middle income	832	38223147	0·63 (0·58–0·69)	Ref
Upper-middle income	892	89366536	0·50 (0·47–0·53)	<0·0001
High income	90	20369560	0·39 (0·33–0·46)	<0·0001
Overall	**1814**	**147959243**	**0·52 (0·50–0·55)**	

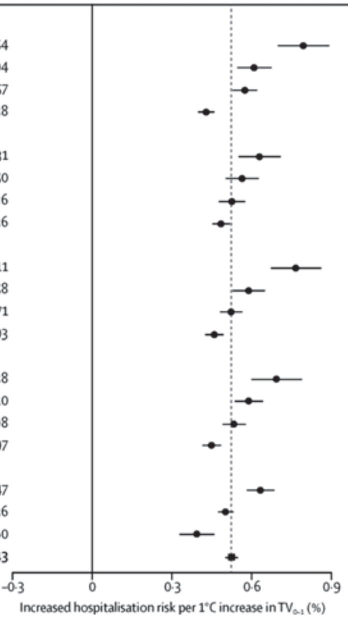

Table 1: Risk of hospital admissions associated with each one-degree Celsius (°C) increase in daily temperature variability (TV). The table shows Brazilian cities, disaggregated by several indicators of socioeconomic level, where the confidence interval (CI) is 95% and the P-value (probability) is 0.05 (5%). As a general rule, the magnitude of risk increases with socioeconomic vulnerability

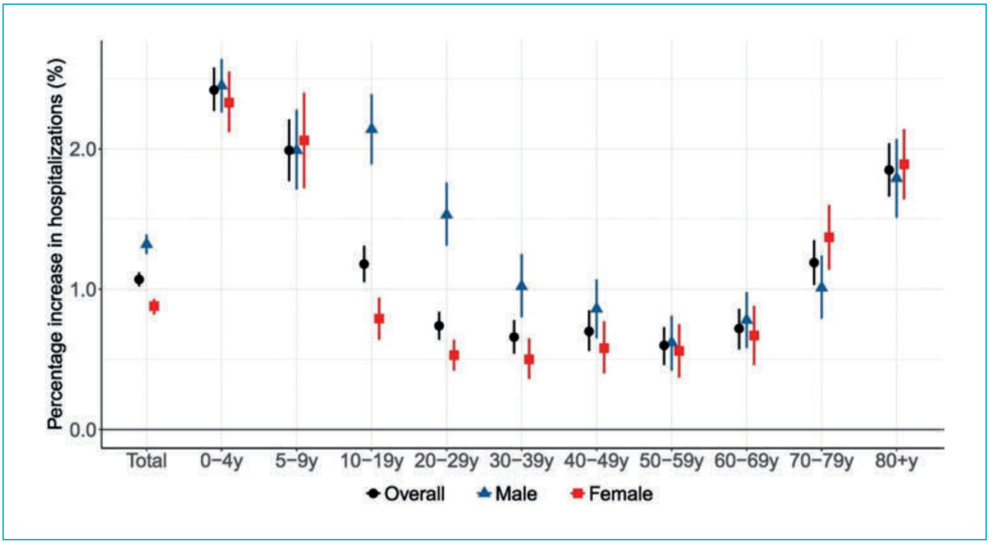

Figure 1: Percentage increase of hospital admissions associated with an inter-quartile change of temperature variability, expressed along different age groups and gender (Zhao, et al., 2018)

urban environment and average household income). In each case, the lowest quartile (Q) of the population experienced the highest increased risk of hospitalization with each one-degree Celsius increase in temperature, as demonstrated in Table 1.

Analysis also illustrated how different age groups exhibited different levels of susceptibility to temperature variability. Children and elderly people, for example, were more likely to be affected by climate-induced health risks (Figure 1).

Age-related vulnerability is probably due to natural processes (i.e. the functions of maturation and senescence). Thermoregulation (the biological mechanism responsible for maintaining a steady internal body temperature) is also markedly affected by age, with early infancy, early childhood and old age all representing periods of thermoregulatory inefficiency.

Finally, there is also evidence of an interaction between short-term heat exposure (heatwaves) and risk of hospitalization due to malnutrition (Xu, *et al.*, 2019).

Temperature comfort zones and mortality

The health comfort zone – defined here as the range of temperature variation without significant adverse health effects – varies within Brazilian cities. In Figure 2, the central dashed line indicates the observed optimal temperature, i.e. the temperature with the lowest risk of mortality. The two lateral dashed lines represent the bottom and top of the temperature range that still does not have a significant impact on health.

The blue and red lines indicate temperatures under or above the optimal temperature. Bars depict the frequency distribution of daily temperature for each city. Cold spells and heatwaves increase mortality risk, but with different intensities and at different temperatures. For example, São Paulo (in the southwest) and Teresina (in the northeast) have distinct thermal comfort zones. In Teresina, the minimum risk

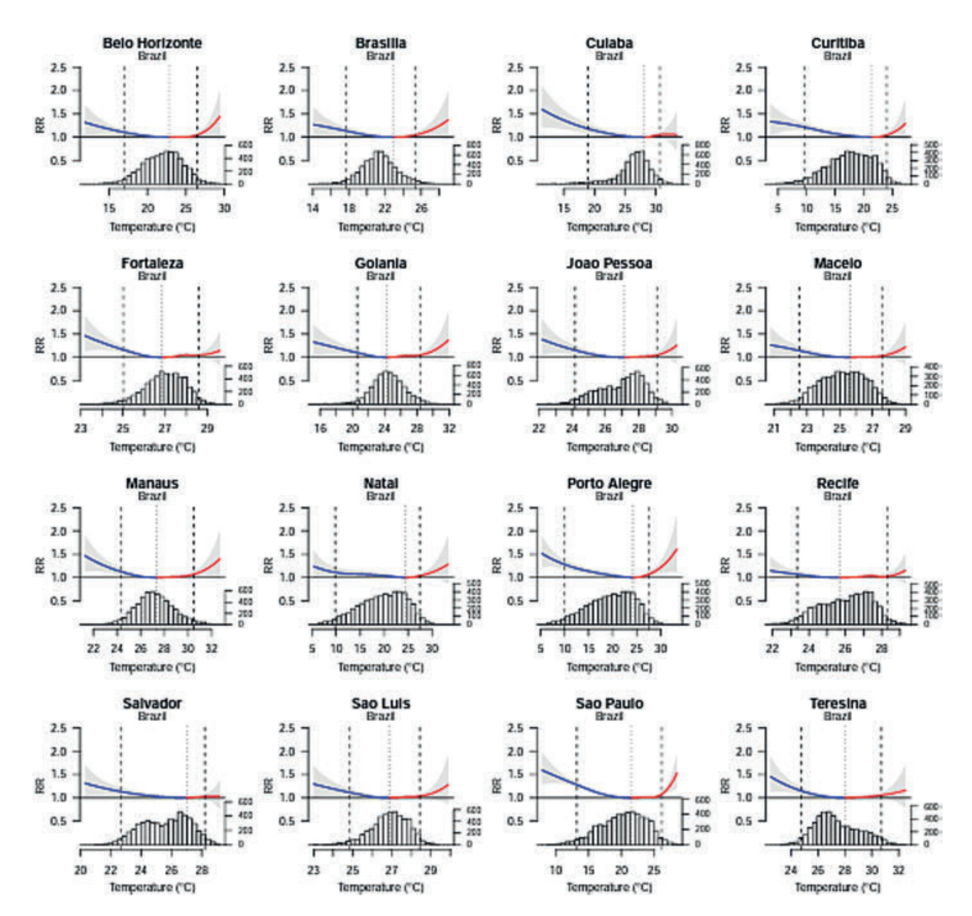

Figure 2: Relative risk (RR) of dying due to ambient temperature in 16 Brazilian cities

temperature is 28 degrees Celsius. In São Paulo, however, 28 degrees Celsius is in the thermal stress zone (Gasparrini, *et al.*, 2015).

Air pollution

Temperature and ambient air pollution interact significantly in promoting adverse health effects (Pinheiro, *et al.*, 2014). Results from this study indicated that children and people experiencing socioeconomic disadvantage, experience increased vulnerability to climate-induced health risks.

Autopsy analysis also demonstrated that levels of inhaled air pollutants are significantly higher in urban dwellers living in underprivileged areas (Figure 3). This is due to exposure to traffic and the modes of transport people use, and is exacerbated, in some cases, by wildfires. There is strong evidence that children and foetuses are particularly vulnerable to ambient levels of air pollution, with adverse consequences that include foetal outcomes such as low birth weight and premature birth (Jacobson, *et al.*, 2014; Saldiva, *et al.*, 2018).

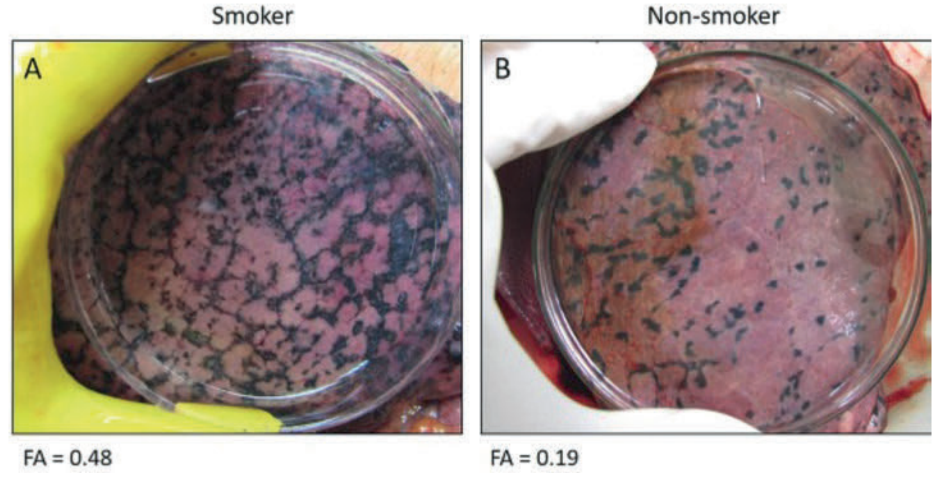

Figure 3: Autopsy images showing the pleural surface of two age-matched dwellers of São Paulo. Fraction area (FA) indicates the amount of pleural surface impregnated by black carbon based on a value of one – i.e. the smoker has 0.48 (48%) black carbon impregnation, while non-smoker has 0.19 (19%). For non-smokers, the study found that the amount of black carbon exhibited had a significant association with socioeconomic deprivation and daily commuting time (i.e. exposure to air pollution from traffic) (da Motta Singer et al., 2023)

The black spots in the pleural surface images (Figure 3) are foci of focal fibrosis with an accumulation of black carbon. The fraction area (FA) occupied by the black spots (0.48 and 0.19) represents a proxy indicator of lifetime exposure to urban particulates, evidenced by their visible component (i.e. black carbon). Non-smokers also exhibit spots of fibrosis with black carbon content. After adjusting for several co-variates (age, intensity of smoking, local traffic, occupation and length of time residing in São Paulo) the study found that the amount of black carbon exhibited had a significant association with socioeconomic deprivation and daily commuting time. As a general conclusion, people experiencing economic deprivation are more exposed to the risk of air pollutant-induced health risks.

Overall, results from this case study showed that extremes of ambient temperature and temperature variability are associated with higher risk of hospital admissions and mortality, notably due to chronic diseases such as stroke, myocardial infarction, congestive heart failure, peripheral arteriopathy, diabetes, kidney insufficiency, asthma and chronic obstructive pulmonary disorder (COPD). Specifically, the study found the following:

1. Temperature-associated health effects were more intense in children and elderly people, as well as amongst those living in areas with social and economic deprivation;
2. Children exhibited a five-fold greater risk of having a hospital admission promoted by temperature variability in comparison with adults;
3. Malnutrition and socioeconomic deprivation significantly aggravated the adverse effects of extreme temperatures;
4. The optimal temperature range varied across the Brazilian territory, probably due to human physiological adaptation as well as urban adaptation;
5. In large metropolitan areas, there were marked territorial differences in optimal temperatures, which were dependent on urban morphology (types of land cover), characteristics of soil occupation, density of green coverage and socioeconomic factors.

Lessons learned

1. Climate abnormalities and ambient levels of air pollution affect children's health.
2. Climate and pollution both interact to create adverse health effects.
3. The level of air pollution creates health effects of different magnitudes depending

on a complex set of factors such as urban islands, poverty (e.g. inadequate housing and sanitation), demography (age, sex and pre-existing health issues) and access to health services.

Finally, public policies that use scientific/quantitative information are necessary, but quantitative analysis alone is not sufficient to address the complex intersections between climate and health. Knowledge produced by researchers in the humanities is also crucial for designing policies and appropriate interventions that consider the values and culture of the people affected. This represents an enormous challenge and implies a close partnership with local communities in policy design and implementation.

One thing is clear; time is of the essence and rapid action is needed to build resilience and protect populations from climate-induced risks to health.

Acknowledgements

Faculty of Medicine of the University of São Paulo and INSPER Laboratory of Urban Health.

Further information on this research is available at:

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