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Impact of urban atmospheric environment on hospital admissions in the elderly

Impacto do ambiente atmosférico urbano nas internações hospitalares de idosos

ABSTRACT

OBJECTIVE: To analyze the impact of intra-urban atmospheric conditions on circulatory and respiratory diseases in elder adults.

METHODS: Cross-sectional study based on data from 33,212 hospital admissions in adults over 60 years in the city of São Paulo, southeastern Brazil, from 2003 to 2007. The association between atmospheric variables from Congonhas airport and bioclimatic index, Physiological Equivalent Temperature, was analyzed according to the district's socioenvironmental profile. Descriptive statistical analysis and regression models were used.

RESULTS: There was an increase in hospital admissions due to circulatory diseases as average and lowest temperatures decreased. The likelihood of being admitted to the hospital increased by 12% with 1ºC decrease in the bioclimatic index and with 1ºC increase in the highest temperatures in the group with lower socioenvironmental conditions. The risk of admission due to respiratory diseases increased with inadequate air quality in districts with higher socioenvironmental conditions.

CONCLUSIONS: The associations between morbidity and climate variables and the comfort index varied in different groups and diseases. Lower and higher temperatures increased the risk of hospital admission in the elderly. Districts with lower socioenvironmental conditions showed greater adverse health impacts.

DESCRIPTORS: Aged. Hospitalization. Cardiovascular Diseases. Respiratory Tract Diseases. Climate Effects. Air Pollution, adverse effects.

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RESUMO

OBJETIVO: Analisar o impacto das condições climáticas intra-urbanas nas doenças circulatórias e respiratórias em idosos.

MÉTODOS: Estudo transversal baseado em 33.212 internações hospitalares de idosos na cidade de São Paulo, SP, de 2003 a 2007. As variáveis atmosféricas coletadas no aeroporto de Congonhas e o índice bioclimático *Physiological Equivalent Temperature* foram analisados segundo o perfil socioeconômico da vizinhança. Análise estatística descritiva e modelos de regressão foram usados.

RESULTADOS: Houve aumento nas internações por doenças circulatórias quando houve diminuição nas temperaturas médias e mínimas. A probabilidade de internações foi 12% maior com diminuição de 1ºC no índice bioclimático e com aumento de 1ºC nas temperaturas máximas no grupo com pior perfil socioeconômico. Houve risco aumentado de internações respiratórias durante má qualidade do ar em distritos com melhor perfil socioeconômico.

CONCLUSÕES: Associações entre morbidade, variáveis climáticas e índice de conforto não apresentaram padrão de comportamento entre os diferentes grupos e doenças. Desconforto para o frio e extremo de calor representaram maior risco para internações de idosos. Distritos com piores condições sociais e ambientais apresentaram maiores impactos à saúde.

DESCRIPTORES: Idoso. Hospitalização. Doenças Cardiovasculares. Doenças Respiratórias. Efeitos do Clima. Poluição do Ar, efeitos adversos.

INTRODUCTION

Global climate changes pose public health risks. However, there is little evidence based on data to build models to predict risks in the context of climate changes, particularly in tropical cities.

Studies on thermal comfort in urban areas apply complex indexes for urban and tourism planning as well as for the assessment of health effects of climate in developed countries. The Physiological Equivalent Temperature (PET) is a complex index that reflects the interactions between humans and the thermal environment.[8,11,10] Knowing local weather phenomena is essential for understanding health impacts on different social groups living in environments with dynamic climatic attributes.

In developing countries population growth, urbanization and increasing consumption go together. It is thus important to understand health-related effects of climate oscillations in the cities to foresee potential effects of future climate changes as trends indicate that cities in developing countries will increasingly contribute to global climate changes.[a] According to Campbell-Lendrum & Corvalán,[5] "decision makers would therefore benefit from assessments that can assist them to select development policies that can bring synergies or optimize trade-offs between protecting the local and global environment while also bringing health gains."

The present study aimed to analyze the impact of intra-urban atmospheric conditions on cardiovascular and respiratory diseases in elder adults.

METHODS

Cross-sectional study based on data from 33,212 hospital admissions in adults over 60 years living in three categories of districts with different socioenvironmental profiles in the city of São Paulo, southeastern Brazil, between 2003 and 2007. São Paulo is located in the Atlantic Plateau at 23°27'S latitude, and has 11 million inhabitants spread over 1,509 km².[b] Urbanization brought about climate changes concerning urban air quality (air pollution), thermal discomfort (heat island), and floods. The study was carried out in the southeast area of São Paulo where

[a] IPCC, 2007: Summary for Policymakers. In: Solomon SD, Qin M, Manning Z, Chen M, Marquis K.B. Averyt M, et al, editors. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2007.

[b] Secretaria Municipal do Verde e Meio Ambiente. Atlas Ambiental do Município de São Paulo. São Paulo; 2004 [cited 2009 Mar 30] Available from: http://atlasambiental.prefeitura.sp.gov.br

Congonhas Airport meteorological station regularly collects reliable data in heavily urbanized districts. Meteorological parameters were obtained for the entire study period (average, minimum and maximum daily temperatures; humidity; wind speed; daily temperature range). Hospital admission information was based on the International Classification of Diseases (ICD-10), Chapter 10, "Respiratory Diseases," and Chapter 09, "Diseases of the Circulatory System." Data were obtained from the Brazilian National Health System Database (DATASUS) of hospital admissions, selected by zip code of residence addresses. There were 33,212 hospital admissions, of which 24,318 due to circulatory diseases and 8,894 due to respiratory diseases.

The PET index was calculated using Rayman version 2.0[c] and based on the following parameters: air temperature (°C), relative humidity (%), average wind speed (m/s), global radiation and latitude, longitude, altitude, and time zone of São Paulo. The PET index was standardized for São Paulo[d] (Table 1). Air pollution indices for 2003 to 2007 obtained from the São Paulo State Environmental Sanitation Technology Company (CETESB) environmental monitoring stations located 400 meters away from Congonhas Airport[e] were used for control.

We selected a local scale that is designed to reflect data from meteorological standard stations (approximately 150 km^2). An area surrounding the meteorological station was defined, covering 14 districts. Our sample included a diversity of urban spaces to understand the association between intra-urban climate and health inequalities (Figure).

The impact of atmospheric variables on morbidity in areas with different socioenvironmental conditions was assessed based on the Environmental Atlas of São Paulo. This index was calculated based on the following indicators: population density; population growth rate; median age; median family income; average education level; infant mortality rate; housing stock (m^2/inhabitant); percentage of slum dwellers; mortality from external causes; vegetation and urban climate. Regression analysis was performed using SPSS version 18.

The 14 districts were combined for a larger sample of hospital data and categorized as higher, intermediate and lower socioenvironmental conditions.

The regression model was built as follows: information of daily admissions was collected in a database; the standardized incidence of daily hospital admissions was calculated based on annual population projections for the age group studied.

Table 1. Outdoor thermal comfort assessed using the Physiological Equivalent Temperature index. City of São Paulo, southeastern Brazil.

PET	Thermal sensation	Physiological stress
<4ºC	Too cold	High cold stress
<12ºC	Cold	Moderate cold stress
<18ºC	Little cold	Little cold stress
18ºC-26ºC	Comfortable	No thermal stress
>26ºC	Little heat	Little hot stress
>31ºC	Hot	Moderate hot stress
>43ºC	Too hot	Too hot stress

PET: Physiological Equivalent Temperature
Source: Monteiro LM, Alucci MP. Outdoor thermal comfort modeling in Sao Paulo, Brazil. In: 25th Conference on Passive and Low Energy Architecture, 22-24 October 2008, Dublin, Ireland; 2008[cited 2009 Mar 17]. Available from: http://architecture.ucd.ie/Paul/PLEA2008/content/papers/poster/PLEA_FinalPaper_ref_365.pdf

$$\text{Rate} = \frac{\text{Hospital admissions per day}}{\text{elderly population living in the southeastern region for that year}} \times 10{,}000 \text{ inhabitants}$$

The median admission rate was calculated and dichotomized into low (patient admissions below the median) and high (patient admissions above the median).

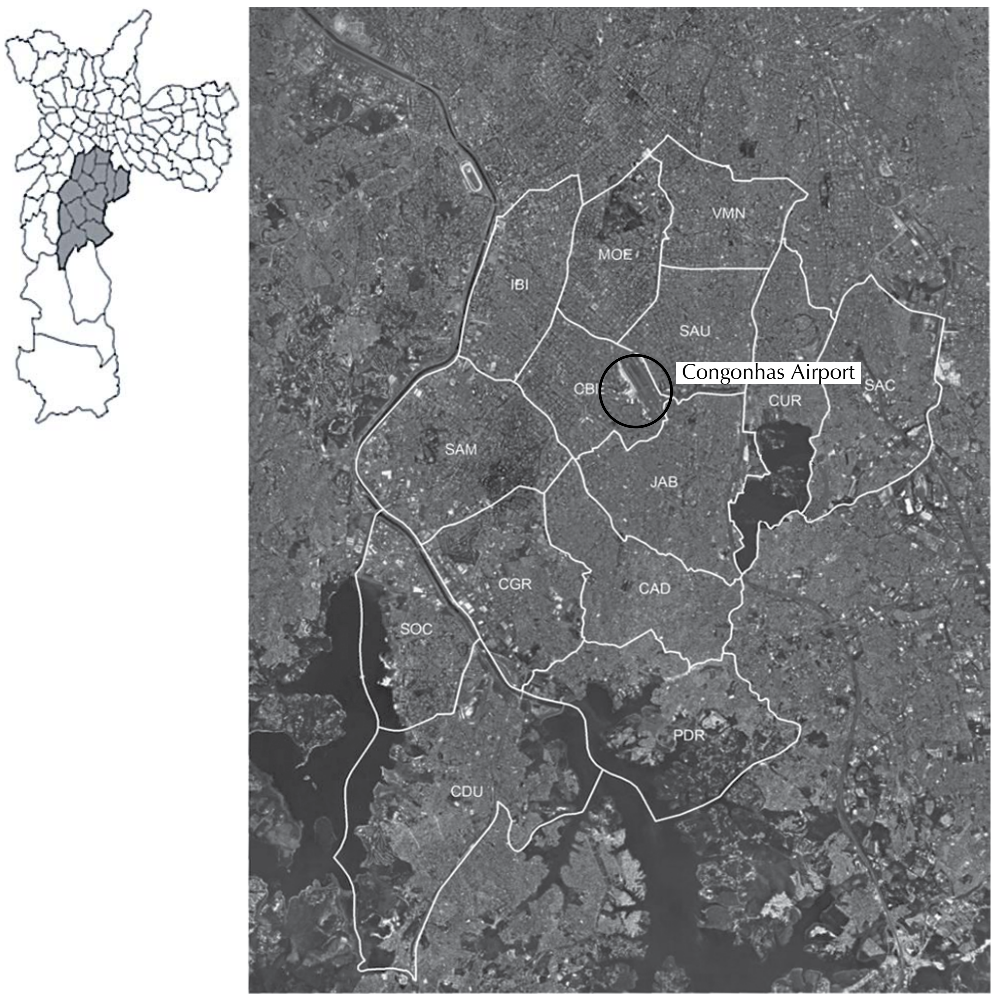
The climate variables selected where those with statistical significance in the logistic regression model. Associations with $p \leq 0.05$ were included in the logistic regression adjusted model.

Air pollution was categorized as adequate (adequate air quality according to CETESB) or inadequate (barely adequate and inadequate air quality).

RESULTS

Atmospheric variables from Congonhas Airport monitoring stations showed an impact of the urban surrounding on the climate. The results showed an association with environmental atmospheric variables in different ways.

[c] University Freiburg. Meteorological Institute. RayMan. Freiburg; 2009[cited 2009 Feb 19]. Available from: http://www.mif.uni-freiburg.de/rayman
[d] Monteiro LM, Alucci MP. Outdoor thermal comfort modeling in Sao Paulo, Brazil. In: 25th Conference on Passive and Low Energy Architecture, 22-24 October 2008, Dublin, Ireland; 2008[cited 2009 Mar 17]. Available from: http://architecture.ucd.ie/Paul/PLEA2008/content/papers/poster/PLEA_FinalPaper_ref_365.pdf
[e] Companhia Ambiental de São Paulo. Relatório de qualidade do ar no estado de São Paulo, 2008. São Paulo; 2009[cited 2010 Apr 17]. Available from: http://www.cetesb.sp.gov.br/Ar/relatorios/RelatorioAr2008.zip



Source: Google Earth 2010.

Figure. Location of Congonhas airport weather station in the southeastern region of the city. São Paulo, Southeastern Brazil.

No significant association between hospital admissions due to circulatory diseases in the elderly and meteorological variables was found in the districts with higher socioenvironmental conditions. There was a significant association (p<0.00) with air pollution: the relative risk of high admission rate was 1.36 times greater in days with inadequate air quality (Table 2).

There was a statistically significant association between hospital admissions and relative humidity and air pollution in districts with intermediate socioenvironmental conditions. A high admission rate was 1.6% more likely with every one-unit decrease in relative humidity (p<0.05) and the relative risk of a high rate was 1.43 times higher in days with inadequate air quality.

There were significant associations (p<0.05) with the PET variables and maximum temperatures in districts with lower socioenvironmental conditions. The PET index showed that the relative risk of high admission rates was 12% higher with every 1°C decrease in the comfort index, and about 1.12 higher with every 1ºC increase in maximum temperatures. Air pollution showed no statistically significant association for the group of districts with lower socio-environmental conditions.

Cold days with wide thermal fluctuations were associated with hospital admissions due to circulatory diseases in the entire southeastern region of São Paulo, regardless of socioenvironmental conditions.

The regression model showed maximum air temperatures and relative humidity as explanatory variables in the group of districts with higher socioenvironmental conditions (Table 3). Relative humidity remained significant (p=0.05) after adjustment. The relative risk of high admission rate was 1.011 with one-unit decrease in relative humidity.

Minimum temperature and wind speed remained statistically significant ($p<0.05$) in the adjusted model for the group of districts with intermediate socioenvironmental conditions. The relative risk of high admission rate was 1.034 with every 1˚C decrease in minimum temperature and elderly were 1.142 more likely to be admitted with decrease in wind speed. The variables daily temperature range and air pollution lost statistical significance in the adjusted model.

There was no association of respiratory disease admissions with atmospheric environmental variables and air pollution in the group of districts with lower socioenvironmental conditions.

DISCUSSION

The intra-urban subdivisions showed complex relationships. There was a strong association between daily hospital admissions due to circulatory diseases and some atmospheric variables – maximum temperature and PET index – in the districts with lower socioenvironmental conditions. There was also an increased risk of excess admissions in days of cold discomfort as well as days of high maximum temperatures in these districts. In areas with lower socioenvironmental indicators people are more vulnerable to atmospheric conditions in the two extremes: cold and hot weather. No statistically significant association was found between atmospheric variables and hospital admissions due to circulatory conditions in districts with higher socioenvironmental conditions. Relative humidity was associated with a higher risk of hospital admission in districts with intermediate conditions, but with weak statistical significance ($p=0.04$). Other studies conducted in São Paulo also reported a relationship between colder days and an increase in circulatory diseases.[7,20]

The etiology of circulatory system diseases is complex and some risk factors include hypertension, smoking, dyslipidemia, diabetes, and obesity. Stressful psychosocial

Table 2. Atmospheric variables and hospital admissions due to circulatory diseases in the elderly, controlled for air pollution, in the southern/southeastern region of the city. São Paulo, southeastern Brazil, 2003 to 2007.

	Congonhas (n = 1722)					
	Higher socioenvironmental conditions (n = 2973)		Intermediate socioenvironmental conditions (n = 9954)		Lower socioenvironmental conditions (n = 11421)	
	RR (95%CI)	p-value	RR (95%CI)	p-value	RR (95%CI)	p-value
PET index	-	-	-	-	0.892(0.84;0.95)	0.00
Max. temp.	-	-	-	-	1.119(1.04;1.19)	0.00
Min. temp.	-	-	1.061(0.95;1.19)	0.31	0.967(0.92;1.01)	0.19
Aver. temp.	-	-	0.907(0.81;1.02)	0.10	-	-
Air RH	-	-	0.984(0.97;1.00)	0.04	-	-
Wind speed	-	-	0.940(0.86;1.03)	0.17	-	-
Air pollution	1.366(1.12;1.66)	0.00	1.434(1.16;1.77)	0.01	-	-

PET: Physiological Equivalent Temperature; RH: relative humidity

Table 3. Atmospheric variables and hospital admissions due to respiratory diseases in the elderly, controlled for air pollution, in the southern/southeastern region of the city. São Paulo, southeastern Brazil, 2003 to 2007.

	Congonhas (n = 1722)					
	Higher socioenvironmental conditions (n = 967)		Intermediate socioenvironmental conditions (n = 3249)		Lower socioenvironmental conditions (n = 4678)	
	RR (95%CI)	p-value	RR (95%CI)	P-value	RR (95%CI)	p-value
PET index	-		-	-	-	-
Max. temp.	0.962(0.90;1.03)	0.24	-	-	-	-
Min. temp.	-	-	0.967(0.94;1.00)	0.03	-	-
Aver. temp.	1.063(0.98;1.15)	0.12	-	-	-	-
Air RH	0.989(0.98;1.00)	0.05	-	-	-	-
Wind speed	-		0.875(0.80;0.96)	0.00	-	-
Thermal amplitude			1.014(0.98;1.05)	0.42	-	-
Air pollution	-		1.178(0.96;1.45)	0.12	-	-

PET: Physiological Equivalent Temperature; RH: relative humidity factors as work-related stress, sadness, depression, anxiety, and strain have been associated with greater risk of myocardial infarction.[18] In our study, climate parameters constitute a risk factor, which is important to understand in view of global climate changes.

Poor urbanization can aggravate the climate effects on health. The association between socioeconomic factors and environment makes the elderly a vulnerable population.

The analysis of respiratory disease admissions showed a better association with minimum temperature and wind speed in districts with intermediate conditions. Confounding factors for respiratory diseases in adults include work, smoking, and nutritional status among others. The causal relationship of atmospheric variables is more complex and less evident.

The variable hospital admissions dichotomized into low and high rates solved the problem of days with zero admissions in the regression model, allowing the analysis of groups of districts with different profiles and to understand health inequalities within a large city.

Studies using other methods pointed to decrease and/or fluctuations in air temperature, decrease in humidity, and increase in temperature range as aggravating factors of respiratory diseases, but in young children.[1,4,14,16]

Research studies in cities in developing countries[12] including São Paulo showed that low temperatures and high temperature range were associated with great seasonal fluctuations of mortality, with highest death rates occurring over relatively colder periods.

The population here studied is sensitive to impacts of climate, but this impact was different for disease groups and different districts, and was dependent on socioenvironmental conditions. Risk factors in subtropical cities may differ from those in higher latitudes.

Comfort indicators are increasingly used as exposure parameters to poor health conditions as, compared to comfortable conditions, cold and hot climate stress aggravate more health problems.[6,9,13,19,22]

Thermal discomfort was associated with higher risk of developing circulatory diseases in people over 60 years in São Paulo. Hot weather is a factor of great concern in developed cities and some studies indicate high death risk among vulnerable elderly during hot days, especially from cardiopulmonary problems.[2,15]

A study[3] pointed out the health effects of heat in people living in cities of developing countries. An increase in mortality risk per unit of temperature increase in those over 65 years old was found in São Paulo.

São Paulo is characterized by wide fluctuations in daily and interday changes in temperature, with frequent changes from a very hot to a very cold day. Daily temperature ranges may exceed 20ºC, especially in the fall and spring, and may have a health impact in the elderly.[17]

A study in São Paulo showed more extreme temperatures and more pronounced temperature fluctuations in slum area than in urban environments with better structure.[21]

Air pollution also increased circulatory and respiratory diseases in the entire population in the southeastern region of the city. However, there was a higher relative risk of high admission rates with inadequate air quality in districts with higher socioenvironmental conditions. This finding may be explained by the location of the monitoring station in those districts more exposed to heavy traffic.

A limitation of the study is that the sample was drawn from SUS hospital data, and refers to a subset of the population that utilizes public hospitals. Non-availability of systematic and reliable information on admissions in private hospitals and with private health insurance limited access to a wider universe. However, as most elderly population cannot afford private health insurance, the study sample may reflect most hospital admissions in those over 60. Hospitalizations reflect an acute impact of a health condition, but climate effects on health may have a diversity of effects, from annoyance to weakness, subclinical and clinical damage and even increased mortality. A more complete database is required to assess all impacts of climate on people's health and more accurate. It is necessary to analyze events that do not necessarily lead to hospitalization. More comprehensive information on diseases must be produced and systematized in order to increase knowledge of atmospheric effects with refined models and to encourage the search for solutions to minimize health impacts.

In tropical urban areas, in addition to investigating the characteristics particular to the climate and social diversity, it is important to understand the relationship between social and environmental inequalities and health-disease. Poor housing conditions such as poor construction, ventilation, and thermal insulation may increase health risks. The literature on this subject is scarce, but future studies may help understand health effects and the potential for adaptation to global climate changes. Research at different geographical scales, from local to microclimate conditions, is needed. The atmospheric environment should be taken into account in environmental health programs. Interventions including urban planning and controlling factors that affect climate (trees, plazas, streets) can reduce emissions of pollutants, among others. At the dwelling level, improvement of thermal insulation may help protect dwellers. Education interventions including awareness campaigns of adverse effects of climate changes and orientation can help protect people against cold/heat and air pollution.

Studies of urban bioclimatology are complex and an interdisciplinary approach is required to build up knowledge on the impact of climate on human health. The present study found associations between morbidity, climate variables, and comfort index, but diverse and specific effects of weather on health. The group of districts studied with lower socioenvironmental conditions showed greater vulnerability to cardiovascular diseases associated to the negative effects of the atmospheric environment. These results may provide input to develop policies for mitigating climate-related risks in cities in the developing world as most studies on health effects of climate have been carried out in cities of developed countries.

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