Circulatory disease mortality rates in the elderly and exposure to $PM_{2.5}$ generated by biomass burning in the Brazilian Amazon in 2005

Mortalidade por doenças circulatórias na população idosa e exposição a $PM_{2,5}$ em decorrência das queimadas na Amazônia brasileira em 2005

Mortalidad por enfermedades cardiovasculares en los ancianos y la exposición a $PM_{2,5}$ como resultado de la quema en la Amazonia brasileña en 2005

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Abstract

The aim of this study was to analyze the association between the exposure to fine particulate matter and circulatory disease mortality rates in the elderly living in the Brazilian Amazon. An ecological study of circulatory disease, acute myocardial infarction and cerebrovascular disease mortality rates in micro areas of the Brazilian Amazon was carried out. The environmental exposure indicator used was percentage hours of $PM_{2.5}$ concentrations > 25μg/m³ divided by the total number of estimated hours of $PM_{2.5}$ in 2005. The association between exposure and circulatory disease mortality rates was strongest in the oldest age group. No significant statistical association was found between cerebrovascular disease mortality rates and exposure. Circulatory disease mortality rates in the elderly living in the Amazon have been influenced by atmospheric pollution from emissions caused by forest fires.

Particulate Matter; Cardiovascular Diseases; Aged; Amazonian Ecosystem

Resumo

O objetivo deste estudo foi analisar a associação da exposição ao material particulado fino com as taxas de mortalidade por doenças circulatórias em idosos na Amazônia brasileira. Trata-se de um estudo ecológico das taxas de mortalidade por doenças circulatórias, infarto agudo do miocárdio e doença cerebrovascular em microrregiões da Amazônia brasileira. O indicador de exposição ambiental foi estimado em porcentagem de horas de $PM_{2,5}$ > 25μg/m³ dividido pelo número total de horas estimadas de $PM_{2,5}$ em 2005. A associação do indicador de exposição com as taxas de mortalidade por doenças do aparelho circulatório foi maior para o grupo mais idoso. A taxa de mortalidade por doença cerebrovascular não mostrou associação com indicador de exposição. As doenças do aparelho circulatório em idosos residentes na Amazônia têm sido influenciadas pela poluição atmosférica resultante das emissões causadas por incêndios.

Material Particulado; Doenças Cardiovasculares; Idoso; Ecossistema Amazônico

Introduction

Atmospheric pollution causes approximately 800,000 deaths each year worldwide, 35,000 of which occur in Latin America [1]. Scientific evidence reveals the effects of exposure to particulate matter on the circulatory system [2,3,4]. According to the World Health Organization (WHO), exposure to elevated levels of atmospheric pollution is associated with an increase in circulatory disease morbidity and mortality [1].

Airborne particulates that are harmful to human health consist of a complex mixture of organic and inorganic compounds [5]. They can be characterized by their physical attributes, which influence their transport and deposition, and their chemical composition, which influences their effect on health [6]. When particulate matter is inhaled it reaches the lungs where it causes inflammation in the respiratory system, which in turn may induce cardiovascular problems. Ultrafine particles may penetrate directly into the bloodstream leading to changes in the systemic system [7,8].

Several studies have shown that exposure to air pollution can lead to an increase in hospitalizations, hypertension cases, ischemic events, arrhythmias and heart failure [4,9,10,11]. Air pollution is an important risk factor for the development of circulatory diseases; in the long term it contributes to the progression of atherosclerotic plaques and deep vein thrombosis, and in the short term it contributes to acute cardiovascular events [2]. Gouveia et al. [12] observed an association between atmospheric pollution and an increase in hospitalizations due to circulatory diseases in the metropolitan area of São Paulo, Brazil. Recent studies also found that changes in blood pressure were associated with exposure to air pollution [13,14,15]. Currently, acute myocardial infarction and cerebrovascular disease are the main causes of death in Brazil [16]. The elderly and patients with a history of cardiorespiratory disease are most susceptible to the effects of air pollution related to the cardiovascular system [1]. The population aged 65 years and over is most susceptible to the cardiovascular system effects of exposure to $PM_{2.5}$ at concentrations exceeding 15µ/m^3 [3].

Biomass burning is one of the most common forms of air pollution, especially in the Amazon region [17]. The concentration of particulate matter resulting from biomass burning is related to an increase in hospitalizations due to respiratory diseases among children and the elderly [6,18,19]. Air quality in the Amazon region is severely affected by levels of atmospheric pollution that are usually much higher than the local air quality standards [20]. One of the specific characteristics of exposure to air pollution in the Brazilian Amazon region is the high concentration of pollutants during the dry season (July to October), principally fine particulate matter known as $PM_{2.5}$. The chemical composition of fine fractions released during the biomass burning process depends on the stage of burning, type of vegetation and the occurrence period [5,21,22]. Despite the high organic matter content of fine fractions (70-92%), the chemical composition of $PM_{2.5}$ during the dry season consists mainly of black carbon (BC), nitrate, potassium (K), chlorine (Cl) and sulfate (SO_4) [21,22,23,24,25,26].

This study, the first to investigate the relationship between exposure to $PM_{2.5}$ and cardiovascular diseases in the Brazilian Amazon, aims to analyze the association between exposure to fine particulate matter, measured in percentage of hours with concentrations above the limit of 25µg/m^3, and circulatory disease mortality rates in the elderly in 2005.

Method

An ecological study of circulatory disease, acute myocardial infarction and cerebrovascular disease mortality rates was undertaken in micro areas of the Brazilian Amazon in 2005. The indicator environmental exposure was estimated based on the annual number of reports of $PM_{2.5}$ concentrations above 25µ/m^3 divided by the total number of estimated hours of $PM_{2.5}$ during 2005.

The spatial units of analysis consisted of 107 micro areas in the Brazilian Amazon that comprises the states of Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Rondônia, Roraima and Tocantins. To facilitate analysis, the state of Maranhão was included in the study despite the fact that only part of its territory belongs to the Amazon Region. This region was chosen due to significant smoke emissions resulting from biomass burning due to forest fires in the region, locally known as *queimadas*.

Information on deaths, classified according to the 10th revision of the International Statistical Classification of Diseases (ICD-10), chapter IX: diseases of the circulatory system (ICD – I), acute myocardial infarction (ICD – I21) and cerebrovascular disease (ICD – I64), was obtained from the Brazilian Health Informatics Department (DATASUS) and stratified by age group (65 to 69 years, 70 to 74 years, 75 to 79 years and 80 years and over). Population data were obtained from the Brazilian Institute of Geography and Statistics (http://www.sidra.ibge.gov.br/bda/

acervo/defalt.asp?z=t&o=3&i=Phttp, accessed on 10/Sep/2010). The indicator environmental exposure consisted of the annual percentage of hours in 2005 with $PM_{2.5}$ concentrations above 25μg/m3, based on the air quality limit set by the WHO [1]. These data were obtained from the Center for Weather Forecasts and Climate Studies of the National Institute for Space Research (Centro de Previsão de Tempo e Estudos Climáticos – CPTEC, acronym in Portuguese). Estimates of levels of $PM_{2.5}$ were obtained through satellite observations, using the model Coupled Aerosol and Tracer Transport Model to the Brazilian Developments on the Regional Atmospheric Modeling System (CATT-BRAMS) that provides measurements of $PM_{2.5}$ levels every three hours. A horizontal resolution of 48km/48km covering the whole South America was used [27,28].

The following control variables were used: number of intensive care unit (ICU) beds per capita in the year 2005, obtained from the National Register of Health Institutions of the Department of Health Care of the Ministry of Health; per capita coverage of Family Health Units (FHU), using data on number of units obtained from the Department of Basic Care of the Ministry of Health divided by the population and multiplied by 100; and municipal Human Development Index (HDI), a general measure of human development based on a combination of education, income, and life expectancy produced by the United Nations Development Program (UNDP) for the year 2000. The year 2005 was chosen for this study because the longest period of drought in recent years in the Brazilian Amazon was recorded in this year [29], which in turn led a high incidence of forest fires in the region.

Data on deaths from circulatory diseases, acute myocardial infarction and cerebrovascular disease were corrected to account for the records of deaths attributed to undefined causes. Although they have reduced in recent years, deaths attributed to undefined causes still remain common among the elderly and for this reason it was decided to correct the data for individuals aged 64 years and over. This procedure may be summarized by the equation Xc = X+M*X/(T-M), where X is the number of deaths from defined causes (circulatory), M is the number of deaths from undefined causes, T is the number of deaths from all causes and Xc is the corrected number of deaths from defined causes. The corrected data was then standardized by age group [30,31].

The strength of the association between the variables was measured by calculating the Pearson coefficient. The exposure indicator average annual percentage of hours of $PM_{2.5}$ exposure was classified into two levels: low exposure (< 5%) and high exposure (≥ 5%). These averages were then compared with cardiovascular disease, acute myocardial infarction and cerebrovascular disease mortality rates across all age groups using the Student's t-test with a significance level of 5%.

The dependent variables cardiovascular disease, acute myocardial infarction and cerebrovascular disease mortality rates were analyzed by age group using multiple linear regression models. The variable acute myocardial infarction mortality rates was normalized in the 75 to 79 years age group using the logarithmic function. The analyses were conducted using the R version 2.9.2 computer program (The R Foundation for Statistical Computing, Vienna, Austria; http://www.r-project.org).

The study was approved by the Research Ethics Committee of the Júlio Muller University Hospital of the Federal University of the State of Mato Grosso (n. 980/CEP-HUJM/2010).

Results

Table 1 shows the cardiovascular disease mortality rates in the micro areas. The average circulatory disease mortality rate was 1.58 per 100 inhabitants. The average cerebrovascular disease mortality rate was 0.56 per 100 inhabitants, which was almost 50% higher than the acute myocardial infarction mortality rate. The annual percentage of hours of exposure to concentrations of $PM_{2.5}$ > de 25μg/m3 varied from zero to 44%. The correlation between annual percentage of hours of $PM_{2.5}$ exposure and cardiovascular disease and acute myocardial infarction mortality rates (33% and 39%, respectively) are statistically significant ($r = 0.33$; $p < 0.001$ and $r = 0.39$; $p < 0.001$). With respect to coverage by FHU, a significant correlation was found only with cardiovascular disease mortality rates. A significant inverse correlation was found between number of intensive care unit beds per capita and cardiovascular disease and cerebrovascular disease mortality rates.

The results of the Student's t-test showed a significant association between exposure and cardiovascular disease mortality rates in all age groups over 65 years of age, varying between 0.62 and 4.10. With regard to acute myocardial infarction mortality rates, a statistically significant association was found for all age groups except the 65 to 69 years and 70 to 74 years groups. No statistically significant association was found in any of the age groups with respect to exposure and cerebrovascular disease. These results show that mortality from cardiovascular disease and acute myocardial infarction in the

Table 1

Descriptive statistics and Pearson correlation matrix for circulatory diseases, acute myocardial infarction and cerebrovascular disease, annual percentage of hours of $PM_{2.5}$ exposure, coverage of Family Health Units (FHU), number of intensive care unit (ICU) beds per capita. Brazilian Amazon, 2005.

Variables	Average (SD)	Minimum-Maximum	Cerebro-vascular disease rate	Acute myo-cardial infarction rate	Cerebro-vascular disease rate	Annual percentage of hours $PM_{2.5}$	HDI	Coverage of FHU	ICU beds per inhabitant
Circulatory disease mortality rate	1.58 (0.51)	0.00-2.70	1.00						
Acute myocardial infarction mortality rate	0.30 (0.21)	0.00-0.69	0.66 (0.000)	1.00					
Cerebrovascular disease mortality rate (CVD rate)	0.56 (0.51)	0.00-1.34	0.64 (0.000)	0.24 (0.012)	1.00				
Annual percentage of $PM_{2.5}$ > 25µg/m³	8.27 (8.87)	0.00-43.89	0.33 (0.000)	0.39 (0.000)	0.06 (0.541)	1.00			
Municipal HDI	0.66 (0.07)	0.51-0.80	0.43 (0.000)	0.37 (0.000)	0.01 (0.854)	0.27 (0.004)	1.00		
Coverage of FHU	73.21 (36.00)	9.43-143.11	0.22 (0.018)	0.22 (0.210)	0.09 (0.317)	-0.12 (0.186)	-0.10 (0.294)	1.00	
ICU beds per inhabitant	31,867.90 (9.43)	127.47-206,719.90	-0.41 (0.000)	-0.09 (0.372)	-0.37 (0.000)	-0.08 (0.432)	-0.30 (0.003)	0.02 (0.819)	1.00

HDI: Human Development Index; SD: standard deviation.

elderly increases with increasing exposure to $PM_{2.5}$ above 25µg/m³ (Table 2).

There was an association between cardiovascular disease mortality rates and annual percentage of hours of exposure to $PM_{2.5}$ concentrations > 25µg/m³ across all elderly age groups. This association is stronger in elderly individuals aged 80 years and over than in any other age group (β_{adj} = 0.05; p = 0.002). An association between exposure to $PM_{2.5}$ and acute myocardial disease mortality rates was found in older age groups (75 to 79 years and 80 years and over). No statistically significant association was found between the variables under study and cerebrovascular disease mortality rates.

With regard to number of intensive care unit beds per capita, the inverse association was stronger in the younger age groups (65 to 69 years and 74 to 79 years). However, this correlation lost statistical significance after adjustment (r^2 = 0.30; p = 0.093). No statistically significant association wad found between number of intensive care unit beds per capita and acute myocardial disease mortality rates.

A significant association was found between HDI and cardiovascular disease in the 70 to 74 years 75 to 79 year and 80 years over age groups and also between the same variable and acute myocardial infarction in the 75 to 79 years and 80 years and over age groups. With respect to coverage by FHU, a significant association was found between this variable and circulatory diseases mortality rates. A significant association was also found between exposure and cardiovascular disease in all age groups except the 65 to 69 years group. The association between this variable and acute myocardial infarction was significant only in the 80 years and over age group (Table 3).

Discussion

This is the first study of its kind to investigate the association between atmospheric pollutants and circulatory diseases in the Brazilian Amazon region. The results show an association between circulatory system mortality rates and exposure to $PM_{2.5}$ among the Brazilian Amazon region's elderly population. In addition, an association between acute myocardial infarction mortality rates and $PM_{2.5}$ exposure was found among older age groups. No association was found between exposure to $PM_{2.5}$ and cerebrovascular disease mortality rates.

This study assessed environmental exposure to particulate matter ($PM_{2.5}$) generated by bio-

mass burning in the Brazilian Amazon and the relationship between this factor and circulatory disease mortality rates in the elderly. Previous respiratory disease studies have shown an association between $PM_{2.5}$ and effects on the respiratory system in the Amazon region using the CATT-BRAMS model, which uses $PM_{2.5}$ as an indicator to estimate air quality [18,19,31,32]. Few studies have shown an association between atmospheric pollution generated by sugar cane burning and damage to the human health [14,33,34].

Exposure to fine particulate matter is an important risk factor for cardiovascular disease mortality, probably due to accelerated atherosclerosis and changes in autonomous heart functions that cause vasoconstriction [10]. Exposure to fine particulate matter can cause the narrowing of the carotid intima [35].

The limit of daily exposure to $PM_{2.5}$ in urban areas set by the WHO is 25µg/m³, regardless of the type of exposure (acute or chronic). Air quality is greatly compromised throughout practically the whole Amazon territory during the dry season [17] when the incidence of forest fires is high. Up to 65% of the particulate matter generated from this biomass burning is made up of fine and ultrafine particles, and can therefore be harmful to human health [23]. It is believed that fine and ultrafine particles are translocated into the bloodstream [36].

Table 2

Comparison of average circulatory disease mortality rates in individuals aged 65 years and over and $PM_{2.5}$ exposure levels in percentage of annual hours above 25µg/m³. Brazilian Amazon micro areas, 2005.

Age (years)	Percentage of annual hours of exposure to $PM_{2.5}$	Average	95%CI		Student's t-test	p-value
Cardiovascular disease mortality rate						
65-69	Low	0.62	0.53	0.71	9.14	0.003
	High	0.81	0.73	0.90		
70-74	Low	1.04	0.90	1.19	11.82	0.001
	High	1.38	1.25	1.52		
75-79	Low	1.69	1.40	1.98	13.30	< 0.001
	High	2.37	2.14	2.61		
80 and over	Low	3.34	2.91	3.77	7.65	0.007
	High	4.10	3.76	4.44		
Acute myocardial infarction mortality rate						
65-69	Low	0.16	0.12	0.19	2.83	0.950
	High	0.20	0.16	0.24		
70-74	Low	0.24	0.18	0.29	2.69	0.104
	High	0.31	0.25	0.37		
75-79	Low	0.24	0.16	0.33	9.77	0.002
	High	0.48	0.36	0.61		
80 and over	Low	0.48	0.40	0.57	4.97	0.028
	High	0.66	0.53	0.79		
Cerebrovascular disease mortality rate						
65-69	Low	0.22	0.17	0.26	5.14	0.250
	High	0.28	0.24	0.32		
70-74	Low	0.37	0.30	0.44	2.05	0.155
	High	0.44	0.37	0.50		
75 to 79	Low	0.69	0.54	0.84	2.27	0.134
	High	0.84	0.71	0.96		
80 and over	Low	1.23	1.04	1.42	0.78	0.378
	High	1.34	1.16	1.53		

95%CI: 95% confidence interval.

Table3

Multiple linear regression analysis of cardiovascular disease, acute myocardial infarction and cerebrovascular disease mortality rates among the population aged 65 years and over and the variables annual percentage of hours of exposure to $PM_{2.5}$ > 25μg/m³, Human Development Index (HDI), Family Health Unit (FHU) coverage, and number of intensive care unit (ICU) beds per capita. Brazilian Amazon, 2005.

Variable	β_{raw}	p-value	$\beta_{adjusted}$	p-value
Cardiovascular disease				
r^2 adjusted 0.30				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.02	0.001	0.01	0.035
HDI	2.84	0.001	2.83	0.001
Coverage of FHU	0.01	0.018	0.01	0.002
Number of ICU beds per capita	-0.01	0.015	-0.01	0.093
65-69 years (r^2 adjusted 0.14)				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.01	0.008	0.01	0.018
HDI	1.27	0.009	0.74	0.147
Coverage of FHU	0.01	0.302	0.01	0.089
Number of ICU beds per capita	-0.01	0.013	-0.01	0.047
70-74 years(r^2 adjusted 0.30)				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.02	0.001	0.01	0.020
HDI	3.10	0.001	2.79	0.001
Coverage of FHU	0.00	0.255	0.01	0.053
Number of ICU beds per capita	0.00	0.005	-0.01	0.036
75-79 years (r^2 adjusted 0.36)				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.05	0.001	0.03	0.003
HDI	8.47	0.001	7.15	0.001
Coverage of FHU	0.01	0.467	*	*
Number of ICU beds per capita	-0.00	0.138	*	*
80 years and over (r^2 adjusted 0.26)				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.06	0.001	0.05	0.002
HDI	6.85	0.001	6.41	0.005
Coverage of FHU	0.01	0.079	0.01	0.005
Number of ICU beds per capita	-0.00	0.203	-0.00	0.679
Acute myocardial infarction				
r^2 adjusted 0.28				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.01	0.001	0.01	0.001
HDI	0.78	0.001	0.69	0.002
Coverage of FHU	0.01	0.033	0.01	0.016
Number of ICU beds per capita	-0.01	0.267	-0.01	0.877
75-79 years (r^2 adjusted 0.20)				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.03	0.001	0.02	0.012
HDI	4.13	0.001	3.04	0.008
Coverage of FHU	0.00	0.720	*	*
Number of ICU beds per capita	-0.00	0.883	*	*
80 years and over (r^2adjusted 0.23)				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.02	0.001	0.02	0.001
HDI	1.10	0.063	-	-
Coverage of FHU	0.00	0.205	0.01	0.034
Number of ICU beds per capita	-0.00	0.805	*	*
Cerebrovascular disease				
Annual hours of $PM_{2.5}$ > 25μg/m³	0.00	0.916	*	*
HDI	-0.01	0.978	*	*
Coverage of FHU	0.00	0.407	*	*
Number of ICU beds per capita	-0.00	0.105	*	*

* Variables not included in the model.

The elderly and patients with a previous history of cardiorespiratory disease are more vulnerable to the effects of biomass burning. Pollution from burning is also an important risk factor for individuals that are more susceptible to circulatory diseases [1]. The National Morbidity, Mortality and Air Pollution Study, carried out in 90 US cities, showed a strong association between high levels of particulate matter and cardiovascular disease mortality in patients over 65 years of age [37], corroborating the present study. It is important to note that these risks are greater among the elderly.

Cardiovascular events such as ischemia and myocardial infarction are more likely to occur when an individual is exposed to $PM_{2.5}$ [4,38]. Mills et al. [39] subjected 20 patients to the physical effort test. Ten of these patients were exposed to 300μg/m³ of $PM_{2.5}$ breathed through tubes and showed clearer signs of myocardial ischemia than the control group.

A study conducted in Singapore showed an increase in the white blood cell count during periods of high air pollution in all individuals from a sample of 30 volunteers with no previous history of disease, due to a greater release of polymorphonuclear cells by the bone marrow. Acute exposure to atmospheric pollutants increases the risk of developing cardiorespiratory diseases [4,40].

The increase in levels of atmospheric pollutants is also associated with sudden death, arrhythmia and acute myocardial infarction, mainly in the elderly [3]. Some studies have shown that the main circulatory system disorders associated with exposure to atmospheric pollutants are due to the effects of acute exposure [10,40,41]. These studies complement the results of this present study because they show the association between deaths due to acute myocardial infarction and exposure to $PM_{2.5}$, especially in the elderly.

Both chronic and acute exposure to atmospheric pollutants increase the risk of death due to a cerebral vascular accident [42]. However, this study did not show any statistically significant association between cerebrovascular disease mortality and exposure to $PM_{2.5}$. This may be partly explained by probable failures in filling in death certificates by doctors who identified the cause of death as circulatory but failed to diagnose the specific event as being cerebrovascular. Multiple diagnoses of cause of death hampers the identification of the underlying cause. The rules for defining the underlying cause of death are defined by the WHO [43,44,45]. In Brazil, hypertension is one of the main causes of death due to circulatory diseases (http://www.datasus.gov.br/datasus.php, accessed on Jun/2011), showing that failures are likely to occur when filling in the death certificate because hypertension is a risk factor and not the underlying cause of death due to circulatory disease [46]. Furthermore, the Brazilian Amazon region has proportionately fewer physicians than other regions and many cities do not have cardiologists (http://www.datasus.gov.br/datasus.php, accessed on Jun/2011) and it is possible that this fact hampers the correct diagnosis of cardiovascular diseases.

The number of intensive care unit beds per capita is an indicator of access to complex health services and therefore quality of care. Acute myocardial infarction is an acute event that requires hospitalization in units with medical technology [47]. However, the treatment of cerebrovascular diseases requires an intensive care unit and preventive care including monitoring blood pressure. Nowadays, these services are performed in family health units through the System of Registration and Monitoring of Hypertensive and Diabetic Patients under the National Plan for the Reorganization of Care for Arterial Hypertension and Diabetes Mellitus.

No significant association was found between family healthcare coverage and mortality rates in most age groups. This may be because health units were implanted in most cities only in 2005 and it is therefore possible that these units were not fully staffed with a complete multidisciplinary team as recommended by the Brazilian Ministry of Health. On the other hand, data shows that the higher the number of ICU beds per capita, the lower the cardiovascular disease mortality rate. A cohort study conducted in the city of São Paulo that compared the ICU needs of four groups of patients showed that although older patients were categorized as priority three and four, younger priority one and two patients were given preference by physicians when filling ICU vacancies [48]. This fact indicates that if the elderly are less likely to get an ICU bed in the city of São Paulo, they are even less likely in regions of Brazil which have fewer ICU beds per capita, such as the Brazilian Amazon. It is important to mention that each Amazon micro area covers a group of five to 11 cities and that 15 of the Amazon micro areas do not have ICU beds. Those individuals in urgent need of an ICU bed living in areas without such facilities are therefore obliged to seek assistance in another micro area, which can reduce their chances of survival.

According to the Brazilian Ministry of Health, in 2004, 78% of the health care network in the Brazilian Amazon region was public. Healthcare coverage was the lowest in the country; 19% of cities had only one kind of health unit, few units offered highly complex healthcare, and a number of cities had no health units whatsoever [49].

The HDI was created by the United Nations to provide a countrywide measure of quality of life and has been adapted to provide measures for states and cities. According to WHO [1], countries with the lowest socioeconomic levels have the highest circulatory disease mortality rates. Brazil is developing, but disparities exist in the Amazon region [50] and the HDI, included in this study as a control variable, adjusted most of the models.

The value of the association between exposure to $PM_{2.5}$ > 80µg/m³ and rates of hospitalization of the elderly due to respiratory disease was β 0.10 [19], in comparison to the association between the cardiovascular disease mortality rate and exposure to a $PM_{2.5}$ concentration > 25µg/m³ which was β 0.05, equivalent to a difference of 50%. Hospitalizations due to respiratory diseases were more common than deaths due to cardiovascular disease. Thus, the results show that pollution ($PM_{2.5}$) has a greater impact on cardiovascular disease mortality rates.

This study provides another tool for monitoring environmental health in the Amazon region and fuels the discussion about the association between exposure to particulate matter and respiratory disease. However, the study has some inherent restrictions that are common to studies carried out using secondary data. In this respect, recent research highlighted the importance of improvements made to the Brazilian information system in recent years [51]. However, the quality of the data on mortality rates used by this study depends on the quality of the cause of death records and the exposure indicator was presented as a measure that combined the annual exposure of each micro area. On the other hand, this methodological option allowed a wider analysis of exposure over a large geographical area.

In conclusion, circulatory disease mortality rates in the elderly living in the Brazilian Amazon have been influenced by atmospheric pollution from emissions caused by forest fires.

Resumen

El objetivo de este estudio fue analizar la asociación entre la exposición a las partículas finas, con tasas de mortalidad por enfermedades cardiovasculares en los ancianos en la Amazonia brasileña. Se trata de un estudio ecológico de las tasas de mortalidad por enfermedades cardiovasculares, el infarto agudo de miocardio y enfermedades cerebrovasculares en las microrregiones brasileñas de la Amazonia. El indicador de la exposición ambiental fue estimado como un porcentaje de horas de $PM_{2,5}$ > 25µg/m³, dividido por el número total de horas estimado de $PM_{2,5}$ en 2005. La asociación del indicador de exposición con las tasas de mortalidad para las enfermedades circulatorias fue mayor en el grupo de mayor edad. La tasa de mortalidad por enfermedad cerebrovascular no se asoció con el indicador de exposición. Las enfermedades cardiovasculares en los ancianos que viven en la Amazonia han sido influenciadas por la contaminación atmosférica, causada por las emisiones de los incendios.

Material Particulado; Enfermedades Cardiovasculares; Anciano; Ecosistema Amazónico

Contributors

K. V. R. Nunes participated in study elaboration and design, data collection and analysis and the discussion and drafting of this manuscript. E. Ignotti collaborated with study elaboration and design, data input, statistical analysis and with drafting this manuscript. S. Hacon contributed to study elaboration and design, participated in data collection and in the revision of this manuscript.

Acknowledgments

The authors are grateful to Dr. Luiz Scala, cardiologist, lecturer in the Faculty of Medicine of the Federal University of Mato Grosso and collaborator on the Public Heath Postgraduate Program, for critically revising this manuscript.

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Submitted on 26/Jun/2012
Final version resubmitted on 30/Oct/2012
Approved on 05/Nov/2012