

Mortality due to diseases of the circulatory system among the elderly population in Brazilian Amazon: temporal and spatial analysis

Mortalidade por doenças do aparelho circulatório da população idosa residente na Amazônia brasileira: análise espaço-temporal

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Conflict of interests: nothing to declare.

Abstract

Introduction: Circulatory Diseases (CD) are the major cause of death among the elderly population in Brazilian Amazon. **Objective:** to analyze standardized mortality rates of diseases of the circulatory system (DCS), according to the main causes of death among the elderly, in microregions of the Brazilian Amazon, in the period of 1998 – 2007. **Methods:** ecological study of mortality rates distribution standardized by CD and corrected by deaths from poorly defined causes among the elderly (≥ 65 years of age) who lived in Brazilian Amazon in the period of 1998 – 2007. The analysis were carried out by the linear regression, trend, and spatial distribution of Kernel. **Results:** We verified an increasing trend in mortality by CD ($\beta_1 = 28.34$ $p = 0.01$), due to the increasing trend in the States of Maranhão and Tocantins. The central region of Mato Grosso, Northern Tocantins, Eastern Pará and Southwestern Maranhão present hot spots with the highest mortality rates. Males present higher rates when compared to females all over the region; rates of mortality due to acute myocardial infarction and hypertensive disease present the same spatial standard of the CD group and the rates of cerebrovascular diseases present a different spatial distribution standard. Increment in mortality rates according to age was observed: the greater the age, the higher is mortality by CD. **Conclusion:** The Brazilian Amazon presents an increasing trend with high rates of mortality by the circulatory diseases, and the geographic areas with the highest rates are around the Brazilian Amazon, in the states of Tocantins, Maranhão and Mato Grosso.

Keywords: Aged. Mortality rate. Cardiovascular system. Amazonian ecosystem. Brazil. Residence characteristics.

Introdução: As doenças do aparelho circulatório (DAC) configuram a principal causa de óbito entre a população idosa na região da Amazônia brasileira. **Objetivo:** analisar as taxas de mortalidade padronizadas de doenças do aparelho circulatório segundo as principais causas de óbito, em idosos nas microrregiões da Amazônia brasileira nos anos de 1998 a 2007.

Métodos: Estudo ecológico da distribuição de taxas de mortalidade padronizadas por DAC e corrigidas pelos óbitos por causa mal definida em idosos, com 65 anos ou mais, residentes na Amazônia Brasileira, no período de 1998 a 2007. As análises foram realizadas por meio de regressão linear, tendência e distribuição espacial de Kernel. **Resultados:** Verifica-se tendência crescente na mortalidade por DAC ($\beta_1 = 28,34$ $p = 0,01$) resultante de tendência ascendente do Estado do Maranhão e Tocantins; a região central de Mato Grosso, norte do Tocantins, leste do Pará e sudoeste do Maranhão representam áreas quentes com as maiores taxas de mortalidade; o gênero masculino apresenta taxas mais elevadas se comparados com o feminino em toda a região; taxas de óbitos por infarto agudo do miocárdio e doença hipertensiva apresentam o mesmo padrão espacial do conjunto das DAC e as taxas de doenças cerebrovasculares apresentam padrão de distribuição espacial diferenciado; foi observado incremento das taxas de mortalidade segundo as faixas etárias, a medida que aumenta a idade dos idosos, eleva-se a mortalidade por DAC. **Conclusão:** A Amazônia apresenta tendência crescente com elevadas taxas de mortalidade por doenças do aparelho circulatório e as áreas geográficas com taxas mais elevadas localizam-se na região do entorno da Amazônia brasileira, nos Estados do Tocantins, Maranhão e Mato Grosso.

Palavras-chave: Idoso. Coeficiente de mortalidade. Sistema cardiovascular. Ecosistema Amazônico. Brasil. Distribuição espacial da população.

In the last two centuries, the world has undergone great economical and social transformation. In this context, circulatory diseases (CD) have emerged as dominant chronic diseases in many parts of the world¹.

According to the International Classification of Diseases (ICD-10), CD are classified as: hypertensive diseases; ischemic heart diseases; pulmonary heart diseases and diseases of pulmonary circulation; cerebrovascular diseases; diseases of arteries, arterioles and capillaries; diseases of veins, lymphatic vessels and lymph nodes.

Age, family history and lifestyle, such as smoking, sedentary lifestyle, excessive stress and bad eating habits may result in obesity, diabetes, hypercholesterolemia and arterial hypertension, risk factors to the development of CD². These are some of the main causes of mortality among middle aged adults and elderly in Brazil and in the world³.

The Amazon region, similar to what occurs all over Brazil, has presented decrease in the mortality and fertility levels, with important demographic and socioeconomic repercussions⁴. According to Becker⁵, the migratory movement to the Amazon has reduced. Nowadays, migration is intra-regional, in other words, populational mobility within the State. Nevertheless, these changes in the migration of youth result in modifications in age composition, increasing elderly population in the region. Health policies implemented for the Amazon region aim to end the focus on primary health services for the cities and organize the services of medium and high complexity in the cities with over 100,000 inhabitants. These measures do not respond the population demand, in addition, there are technological deficiencies in comparison to other regions of Brazil⁶.

This study aims to analyze standardized mortality rates of CD, according to the main causes of death among the elderly in microregions of the Brazilian Amazon, in the period of 1998 – 2007.

Methodology

Design of the study

Ecological epidemiological study of the distribution of standardized rates of mortality due to CD (chapter IX of the 10th Revision of the International Classification of Diseases - ICD-10) among the elderly who lived in the Brazilian Amazon, in the period of 1998 - 2007.

Area and population studied

This study uses data from the states which are part of the Brazilian Amazon: Acre, Amapá, Maranhão, Mato Grosso, Pará, Rondônia, Roraima and Tocantins. The state of Maranhão, despite not having its whole territory included in Brazilian Amazon, was fully included in this study in order to facilitate the analysis and comparisons with others studies carried out, regarding air pollution and health effects in the Amazon. This area was chosen to be studied due to the important transformations undergone with the process of occupation over the last years. Amazonia comprises nine states and it is divided in 107 microregions, each of them consisting of a set of neighboring municipalities. The purpose of the micro is to integrate the organization, planning and execution of public functions of common interest based on economic and social similarities⁷. The population selected for the study was the elderly with 65 years of age or more, who died in the period of 1998 - 2007, according to place of residence. Developed countries criteria for defining the group of elders was used (≥ 65 years of age) to make comparisons with international studies⁸.

Database

Database of deaths due to circulatory diseases are from DATASUS and are part of the Mortality Information System (*Sistema de Informação de Mortalidade - SIM*)⁹. Population estimates by age were obtained

from the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística - IBGE*)¹⁰.

Database management

Due to the great number of deaths from poorly defined causes, notified deaths from CD were corrected by deaths from poorly defined causes. Mortality rates from poorly defined causes have decreased over the last years in Brazil¹¹, although it is still expressive in the Amazon region. These corrections were made using the proportion between deaths from CD and the total number of deaths. It has been assumed that the distribution of causes of death among poorly defined deaths is similar to the distribution of causes of death from defined causes. This procedure was followed for all years analyzed and may be summarized by the following equation: $X_c = X + M * X / (T - M)$, in which X is the number of death from specific causes (circulatory), M is the number of deaths from poorly defined causes, T is the number of deaths from all causes and X_c is the corrected number of deaths from specific causes. After the corrections, adjustments were made through standardization, which resulted in mortality rates from poorly defined causes corrected and adjusted by age^{12,13}.

The annual standardized mortality rate (SMR) from CD was calculated (1998 - 2007); subsequently, the same calculations were made considering sex and specific causes of mortality due to CD (acute myocardial infarction, hypertensive disease, cerebrovascular disease) for the year 2007, considering all microregions of the Brazilian Amazon. In this study, we chose the microregion as the minor unit of analysis, to compensate the instability of the SMR, in consequence of the variation in the size of population among the municipalities.

The standardizing of the mortality coefficient according to the age group (65 - 69, 70 - 74 and 80 years of age) was calculated by the direct method, considering as the standard population the average of populations in the age groups and in the period, for the country. Standardization was important because of the

differences in population age in the Brazilian Amazon microregions¹⁴.

Data analysis

The annual SMR from CD (chapter IX of ICD-10) was calculated. The trend analysis of the mortality coefficients was done using simple linear regression for states during the period of 1998 to 2007. The statistical models considered each mortality rate as a dependent variable (Y) and the years being analyzed as independent variable (X). The models of simple linear regression were adjusted for each temporal series. It was decided to centralize the independent variable by subtraction of the midpoint of each value of the series ($X - (2002 + 2003/2)$), aiming to avoid autocorrelation among the equation terms in regression. Thus, the estimate model may be written as: $Y = B_0 + B_1(X - (2002 + 2003/2))$, in which Y represents the mortality coefficient, B_0 is the average coefficient for the analyzed period, B_1 is the average annual increment and X represents each year analyzed in the series.

Trend was considered significant when the adjusted model got $p < 0.05$ (5% of the significance level). The determination coefficient (r^2) was used as a step of precision of the models.

To represent the distribution of the mortality rates due to circulatory diseases, we created maps of areas with the highest concentration of events or hot spots for each microregion of the states in Brazilian Amazon.

The technique for geographical representation of the mortality rates was the density estimator by two-dimensional Kernel¹⁵, using as parameters a 269 columns grid about the events and with algorithm of quartic function with adaptative radius. The adaptive radius estimates, automatically, a width considering the number of events and the total extension of the analyzed area. In the matrix calculation, we considered the microregions centroids, but for better visualization, the vector map was drafted by the States.

Through spatial distribution analysis of mortality rates due to circulatory diseases,

acute myocardial infarction, cerebrovascular disease and hypertensive disease, it was possible to identify the microregions of the Brazilian Amazon with the highest magnitude of the disease. The 9.2 version of the Esri Arcgis software was used. We used the setting for the local empirical Bayesian approach for the analysis of SMR. Therefore, the SMR set was generated, taking into account an array of contiguous neighborhood. The empirical Bayesian local method weighs the value of each microregion by averaging the values of its neighbors, taking into consideration a population of 100,000 inhabitants¹⁵.

The Increment of SMR, according to the causes, was calculated after correction by deaths, from poorly defined causes, for the age groups of 65 to 69 years of age (A), 70 to 74 years (B), 75 to 79 years (C) and over 75 years of age (D), resulting in the equation $((B/A) - 1) * 100$ for the increment of A to B and so successively.

Results

The SMR from CD among elderly population living in Brazilian Amazon shows an increase trend. However, among the states, it is possible to notice the increasing trend only in the states of Maranhão and Tocantins, a decreasing trend in Amapá and lack of trend for the other states. The results of the equations of linear trend of the SMR show that the history series of Amazon is statistically significant. It is possible to notice statistically significant increasing trend of rates for Maranhão and Tocantins; on the other hand, the trend is decreasing for the state of Amapá (Figure 1 and Table 1)

The spatial distribution of mortality from circulatory diseases among the elderly over 65 years of age in 2007, presents hot spots with higher mortality rates in the central region of Mato Grosso, the north of Tocantins, the east of Pará, Central Rondônia and the southwest of Maranhão. Although Mato Grosso has not showed an increasing behavior, this state concentrates in its microregions the highest SMR for the year 2007. The geographical

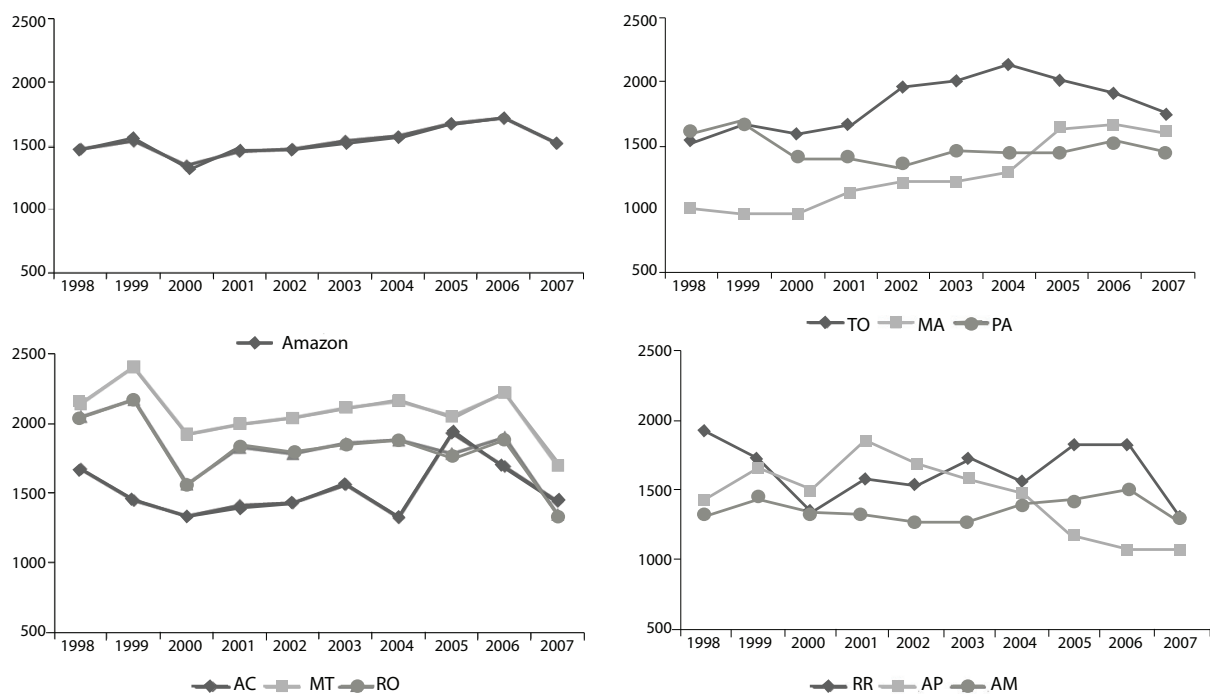


Figure 1 - Standardized mortality rates from diseases of the circulatory system (per 100,000 inhabitants) in the elderly population (≥ 65 years of age), according to the states of Brazilian Amazon, 1998 – 2007.

Figura 1 - Taxas de mortalidade padronizadas por doenças do aparelho circulatório (por 100.000 habitantes) na população de 65 anos e mais, segundo unidades da federação da Amazônia brasileira 1998 – 2007.

Table 1 - Estimates of linear regression equation parameters of the series of standardized mortality rates from diseases of the circulatory system, according to the States of Brazilian Amazon, 1998 – 2007.

Tabela 1 - Estimativas dos parâmetros da equação de regressão linear da série de taxas de mortalidade padronizadas por doenças do aparelho circulatório, segundo unidades de federação da Amazônia brasileira, 1998 – 2007.

States	β_0	β_1	p-value	r^2	Tendency
Acre	-52.75	14.89	0.51	0.056	→
Amapá	175.84	-67.77	0.03	0.484	↓
Amazonas	66.91	4.31	0.65	0.027	→
Maranhão	-455.33	94.59	0	0.877	↑
Mato Grosso	136.62	-25.09	0.25	0.163	→
Pará	510.59	-13.48	0.25	0.162	→
Rondônia	226.25	-41.73	0.1	0.3	→
Roraima	92.35	-15.59	0.55	0.046	→
Tocantins	-548.58	49.44	0.04	0.427	↑
Amazônia brasileira	-85.24	28.34	0.01	0.544	↑

β_0 : average coefficient estimate for the period (per 1000,000 inhabitants); β_1 : average annual increment estimate
 β_0 : estimativa do coeficiente médio do período (por 1000,000 habitantes); β_1 : estimativa do incremento médio anual

microregions of Alto Araguaia, Aripuanã and Sinop reached rates of 2818.1, 2362.7 and 2341.5, respectively.

When the spatial distribution according to gender was analyzed, it was noticed that, despite of the same spatial standard, the SMR for males presents greater geographical extension and higher intensity of hot spots, if compared to females (Figure 2).

In terms of mortality rates from the specific and more relevant diseases of the circulatory system in the year 2007, rates for acute myocardial infarction and hypertensive disease present the same spatial pattern of the group of CD. The rates of cerebrovascular diseases present a different pattern of spatial distribution with hot spots in all states. However, the most evident geographic areas are the same for infarctions and hypertensive diseases (Figure 3).

In Table 2, it can be observed that with the increasing age of the elderly, the mortality due to circulatory diseases also increases. The state of Mato Grosso shows the highest mortality rates for the following age groups: 65 – 69 years of age; 70 – 74; and 75 – 79. For the group over 80 years of age, the state of Tocantins stands out, presenting the highest rates. According to the calculation of increment for the mortality rates for age, with increasing age of the elderly, rises the mortality from CD. The increments vary from 19 to 279%. The State of Roraima shows the highest increment for ages 65 to 69, 70 to 74 and 75 to 79 – 80 years of age or over 80. The smallest increment was seen in the State of Amapá of 70 to 74 and from 75 to 79 years of age. However, almost all states show present higher increment for ages 75 to 79 – 80 years, or over 80 years of age, apart from the states of Amapá and Roraima.

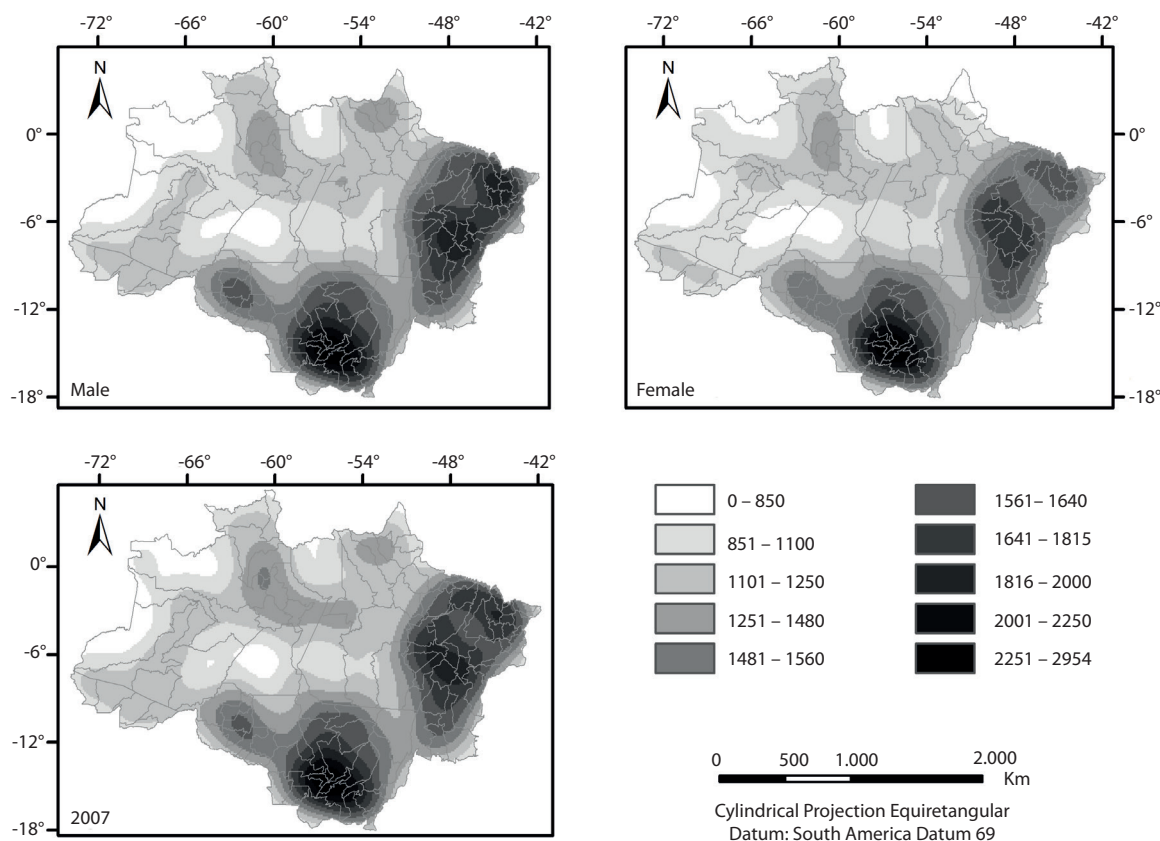


Figure 2 - Kernel distribution according to mortality rates from diseases of the circulatory system (per 100,000 inhabitants) among the elderly over 65 years of age in the microregions of Brazilian Amazon, 2007, according to gender.

Figura 2 - Distribuição de Kernel segundo as taxas de mortalidade por doenças do aparelho circulatório (por 100.000 habitantes) nos idosos com mais de 65 anos nas microrregiões da Amazônia brasileira em 2007 segundo gênero.

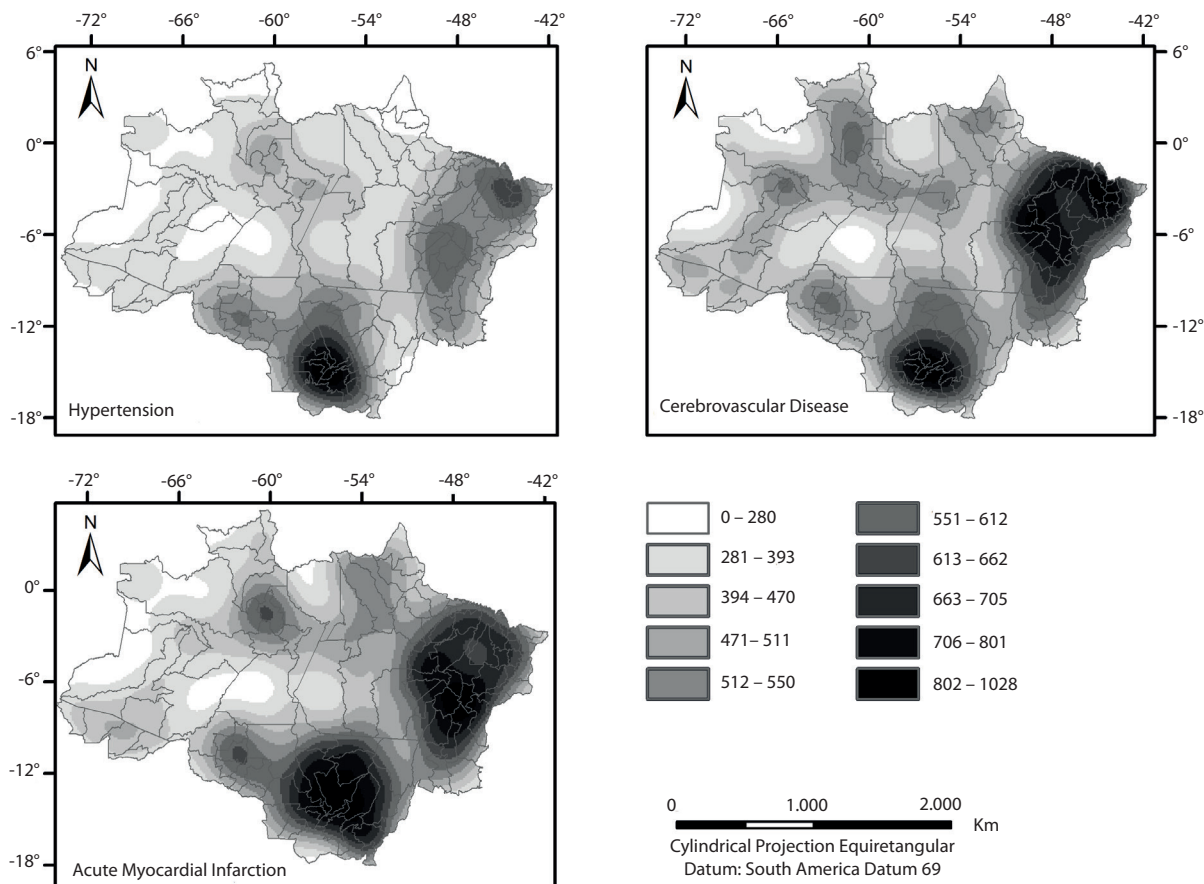


Figure 3 - Kernel distribution according to mortality rates from acute myocardial infarction, cerebrovascular disease, hypertensive disease (per 100,000 inhabitants) among the elderly over 65 years old in the microregions of Brazilian Amazon in 2007.

Figura 3- Distribuição de Kernel segundo as taxas de mortalidade por Infarto agudo do miocárdio, doença cerebrovascular, doença hipertensiva (por 100.000 habitantes) nos idosos com mais de 65 anos nas microrregiões da Amazônia brasileira em 2007.

Table 2 - Percentual increment of standardized mortality rates from diseases of the circulatory system according to age in elderly people (per 100,000 inhabitants) in Brazilian Amazon, 2007.

Tabela 2 - Incremento percentual das taxas de mortalidade padronizadas por doenças do aparelho circulatório segundo grupos etários em idosos (por 100.000 habitantes) na Amazônia brasileira no ano de 2007.

States	65 to 69	Increment	70 to 74	Increment	75 to 79 years	Increment	80 or more
	years of age		years of age		of age		years of age
	(A)	(A/B)	(B)	(B/C)	(C)	(C/D)	(D)
Acre	676.74	53	1038.42	49	1542.34	118	3364.77
Amapá	534.43	81	966.4	19	1151.57	67	1925.35
Amazonas	559.2	65	923.25	53	1411.9	134	3306.34
Maranhão	740.55	54	1139.2	48	1688.31	117	3661.64
Mato Grosso	884.61	56	1377.51	60	2201.26	75	3854.08
Pará	671.17	55	1041	51	1572.49	116	3393.5
Rondônia	698.73	86	1296.73	30	1679.72	86	3116.88
Roraima	319.85	279	1212.96	22	1480.89	139	3543.86
Tocantins	741.4	70	1258.75	65	2079.44	107	4308.77

Discussion

The Brazilian Amazon region presents an opposite trend in relation to what has been happening in Brazil and all over the world, with increment in the mortality rate due to circulatory diseases. Mortality from CD is the main cause of death in Brazilian Amazon, with high rates, especially in the microregions around this area. This region is called “deforestation arc”, characterized by the territorial occupation occurred in the last three decades¹⁶. Nevertheless, when analyzed the standardized mortality rates, according to the states, it is possible to notice an increasing behavior for the states of Maranhão and Tocantins. On the other hand, the state of Amapá shows a decreasing trend and the other states do not present any trend. Thus, the increasing trend verified for Amazon, was influenced by data from the states of Maranhão and Tocantins.

Studies about mortality trends, due to CD in Europe, United States and Japan, in the period of 1965 to 1998, showed reduction in mortality, however, in some countries of Eastern Europe, mortality due to CD is still very high¹⁷. Several studies have shown decrease in the trend of mortality from CD in Brazil^{3,18} and in the world^{12,19}. Decrease in mortality rates from CD observed in the world in the last decades is due to the control of the risk factors, the improvement in socioeconomic conditions, and the scientific and technological knowledge, which together could be associated with more adequate diagnosis and treatment for these diseases²⁰.

According to Mansur et al.²¹, although one of the main causes of death in Brazil in the period of 1979 to 1996, was the CD, there was a decreasing trend in mortality from these diseases. Studies about the risk of death from CD in 11 capital cities in Brazil (1980 – 1998) showed decrease in mortality in most of these cities, with the exception of the cities of São Paulo and Brasília. We believe that the increment in risk in this capital cities is a result of the improvement in diagnosis, the increasing in urbanization or worse socioeconomic conditions¹⁸. On the other hand, the study of mortality trend for the elderly, carried out in

the State of Mato Grosso, shows an increase in mortality rates from diseases of the circulatory system, especially for groups of more advanced age¹³, what meets the findings of this study to Brazilian Amazon. Nevertheless, the authors present a 20-year-historic series for the state of Mato Grosso (1996 – 2007), and that is possibly because this study presents different results in relation to previous findings.

The increasing trend of mortality due to circulatory diseases in Brazilian Amazon may be partially explained by the demographic transition process, since the increase in life expectancy and the aging of population mean an increase in mortality from chronic degenerative diseases, such as cancer and circulatory diseases¹. According to Moreira⁴, as in other regions of the country, Amazon starts to suffer from growth in the proportion of elderly population as a consequence of the decrease in fertility rates and the aging of its immigrants. The risk of death increases as age advances for each of the diseases of the circulatory system, for both sexes²².

Nowadays, with the scientific and technologic evolution, deaths among population in general have decreased; however, for the more advanced age groups, the number of years to be lived is usually more discrete, because there is a biological limit for the human life. The elderly population is considered vulnerable and more susceptible to cardiovascular system involvement. With the aging process, the elastic fibers decrease whereas the collagen fibers increase, there is a calcium deposit on the aorta, arteries and arterioles walls, as this is called arteriosclerotic process²³.

When analyzing the geographic distribution of mortality from specific diseases of the circulatory system, it was possible to notice that there was higher dispersion of hot spots for cerebrovascular disease. Taking into consideration that the maps were created from the standardized mortality rates, it can be observed that the population density does not influence in the results, mainly when it refers to mortality from cerebrovascular disease, because this disease presents a different spatial distribution standard, with areas little populated,

as the North of the state of Amazonas. According to Souza et al.²⁴ and Costa et al.²⁵, the cerebral vascular accident (CVA) is the main cause of death in Brazil. This study shows that the Amazon region is not different from the rest of the country, concerning mortality from cerebrovascular disease.

Among the groups of circulatory diseases, the acute myocardial infarction (AMI) is one of the quality of health services indicators standard, because it is an acute event with simple diagnosis that requires hospitalization with specific medical technology²⁶. According to Rogers et al.¹⁹, in a study from 1990 to 1999 with 1.5 million Americans, the reducing deaths due to acute myocardial infarction is a result of faster administration of the thrombolytic treatment, the increasing use of angioplasty and pharmacological therapies. Knowing the high mortality rates from AMI in Amazon, this is an indicative of likely failures in health services in the region.

According to Becker²⁷, the grown of the urban population in Amazon was not accompanied by implementation of infrastructure to ensure the minimal conditions of life quality. Poor medical technology added with the poor conditions of life may be associated with the increase in mortality rates from CD in that area.

According to Nogueira et al.²⁸, male individuals show, in any age group, higher mortality rates if compared to female ones. This fact confirms the results verified in this study. The higher the age, the higher the mortality rates from CD in all states of the Brazilian Amazon. Not finding a growing trend in the period of 10 years of study for the state of Mato Grosso does not reflect a lower prevalence of CD in this state. The state of Mato Grosso presents the highest mortality rates for the elderly over 65 years of age. A study about mortality from cardiovascular disease in the city of *Niteroi* from 1998 to 2007

shows decrease in mortality rates among men and women in all age groups, however, this tendency diminishes with age and there is an increase in mortality rates from cerebrovascular disease can be observed²⁹. During the period analyzed by Lima and Costa et al.²⁵, from 1980 to 1991, in a mortality diagnosis among the elderly in Brazil, diseases of the circulatory system appear in the first position among the causes of mortality, significantly increasing with age.

Spatial distribution of mortality from CD in 2007 highlights the States of Maranhão, Tocantins, Mato Grosso and Pará, coinciding with the area where deforestation is more frequent in Brazil¹⁶.

In the last 30 years, Amazon region has undergone a great process of colonization, many times encouraged by government programs³⁰. Amazon is considered the largest biodiversity reserve of the planet. However, there are changes in occupation and use of the soil, which causes environmental impacts with significant emissions of air pollutants³¹ that are likely risk factors to the development of diseases³², including circulatory^{33,34}.

Over the last years, there has been an improvement in quality of information services of mortality in Brazil, even decreasing the registers of mortality from poorly defined causes³⁵. However, this study has as limitations particular aspects of studies carried out with secondary databases, as the quality of registers of mortality from diseases of the circulatory system. Nevertheless, it was attempted to reduce possible bias through the correction of mortality rates from poorly defined causes, standardization of rates according to age group and adjustments in trend analysis in order to avoid autocorrelation.

In conclusion, the Amazon shows increasing trend of the mortality rates from circulatory, and the geographic areas with the highest rates are located in regions around Brazilian Amazon, in the states of Tocantins, Maranhão and Mato Grosso.

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