

Evolution of Mortality from Diseases of the Circulatory System and of Gross Domestic Product per Capita in the Rio de Janeiro State Municipalities

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Abstract

Background: Diseases of the circulatory system are the leading cause of death in Brazil and the world, falling progressively during the twentieth century, preceded by an increase in Gross Domestic Product.

Objective: To correlate balanced and adjusted mortality rates from circulatory system diseases in the municipalities of Rio de Janeiro state between 1979 and 2010 with the gross domestic product per capita (GDPpc) beginning in 1950.

Methods: Population and death data were obtained from the Department of Information and Computer Services at the National Health System/Brazilian Ministry of Health (Departamento de Informática do Sistema Único de Saúde - Ministério da Saúde - DATASUS-MS). Mortality rates were calculated for Ischemic Heart Disease (IHD), Cerebrovascular Disease (CBVD), and Circulatory System Disease (CSD); adjusted by the direct method; and balanced for ill-defined causes. The GDPpc data were obtained from the Institute of Applied Economic Research (Instituto de Pesquisas Econômicas Aplicadas - IPEA). Mortality rates were correlated with socioeconomic indicators using Pearson's linear correlation coefficient to determine the annual optimized lag time. Regression slope coefficients between the dependent disease and independent socioeconomic indicator were estimated.

Results: In recent decades, there has been a reduction in mortality from CSD in all Rio de Janeiro state municipalities, mainly due to a decline in mortality from CBVD. The decline in mortality from CSD was preceded by an increase in the GDPpc, and a strong correlation was observed between this index and mortality rates.

Conclusion: The evolution of the variation in GDPpc demonstrated a strong correlation with the reduction in CSD mortality. This relationship demonstrates the importance of improving the living conditions of the population to reduce cardiovascular mortality. (Int J Cardiovasc Sci. 2018;31(2)123-132)

Keywords: Stroke / complications; Mortality; Risk Factors; Gross Domestic Product.

Introduction

The health conditions of the populations are influenced in a complex way by social determinants, such as income and wealth distribution and education, as if these indicators were interdependent risk factors for the occurrence of diseases.¹ During the 20th century, almost the entire world has experienced an improvement in socioeconomic indicators, in addition to a drop in the general mortality rates, with a consequent increase in the life expectancy of

the populations. Furthermore, there was a change in the epidemiological profile, in which communicable diseases were no longer the major causes of death, being replaced by non-communicable diseases, mainly diseases of the circulatory system (DCS), which are the leading cause of mortality worldwide, corresponding to approximately one third of all deaths. Nevertheless, the deaths from DCS have shown a progressive reduction from the mid-20th century in developed countries, and, in Brazil, that reduction has been observed since the 1970s.²⁻⁵

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In 2010 and according to data from the Brazilian Institute of Geography and Statistics (IBGE), the Rio de Janeiro State, then divided into 92 municipalities, had 15,989,929 inhabitants, with a population density of 365.23 inhabitants/km². The Gross Domestic Product (GDP) of the Rio de Janeiro State corresponds to 11.3% of the Brazilian GDP.⁶ The Rio de Janeiro State municipalities have a very heterogeneous socioeconomic structure. Some municipalities, such as Porto Real, have a GDP *per capita* (GDPpc) that exceeds R\$ 200,000.00, and others, such as Japeri, have a GDPpc of R\$ 5,000.00, similar to that of some countries, such as Congo, Samoa and Swaziland, and much lower than that of the Brazilian mean of R\$ 19,000.00.⁶ Some Rio de Janeiro State municipalities, such as São Francisco de Itabapoana, have a poverty index greater than 36%, while others, such as Niterói and Volta Redonda, have a poverty index lower than 10%. The poverty index considers three variables: the short duration of life (the population percentage that does not reach the age of 40 years), the lack of elementary education (the illiterate percentage of the population), the lack of access to public and private resources (the population percentage that has access to neither health care service nor potable water, and of malnourished children).⁷

Some studies have assessed the evolution of mortality from DCS and its major two subgroups in Brazil, ischemic heart diseases (IHD) and cerebrovascular diseases (CBVD),^{5,8-11} however, studies correlating that mortality with socioeconomic indicators per municipality are rare.

Therefore, a study with the Rio de Janeiro State municipalities, which have a varied and heterogeneous socioeconomic structure, will allow us to build models about the evolution of the mortality rates from DCS and of GDPpc, estimating correlations between those variables aiming at suggesting factors involved in reducing the mortality rates from DCS, IHD and CBVD.

Methods

This study collected data on GDPpc and mortality in Rio de Janeiro State municipalities, which were analyzed according to the geopolitical structure of the year 1950, gathering the emancipated municipalities with their original headquarters from that date on. Those aggregates of municipalities caused a reduction in the total number of Rio de Janeiro State municipalities from 92 in 2010 to 56 aggregates for this study analysis.

In addition, those aggregates of municipalities were analyzed by region. This study used the regional division

proposed by the Rio de Janeiro State Secretariat of Health with a change, subdividing the Metropolitan region into the Metropolitan Belt, which comprises all municipalities in the region except for the municipalities of Rio de Janeiro and Niterói, which constituted two autonomous regions. The other regions, Mid-Paraíba, Mountain, Northern, Coastal Lowlands, Northwestern, Southern-Central, and Ilha Grande Bay, are those defined by the Rio de Janeiro State Secretariat of Health.¹²

The GDP data were obtained from the Applied Economic Research Institute (*Instituto de Pesquisa Econômica Aplicada*)¹³ for the years 1949, 1959, 1970, 1975, 1980 and 1985 to 2010. The population data were obtained from the IBGE⁶ for the general census years (1950, 1960, 1970, 1980, 1991, 2000 and 2010) and population counting (1996). Intercensal population estimates were calculated with the arithmetic method by use of the census years or population counting immediately before or after. Those estimates were performed for the fractions corresponding to the age groups, at 10-year intervals, for each sex. The GDPpc was calculated by dividing the absolute and the municipality GDP by the population in the corresponding year. Then the GDPpc was converted into dollars (1 dollar = 3.2 *reais*, currency exchange rate of April 2015).

To calculate the mortality rates, the mortality data restricted to adults aged 20 years and older from the database DATASUS-MS were analyzed.¹⁴ Such data were divided into the major fractions of interest in this study: DCS, corresponding to the codes listed in chapter VII of ICD-9¹⁵ or chapter IX of ICD-10;¹⁶ IHD, corresponding to the codes 410-414 of ICD-9 or codes I20-I25 of ICD-10; CBVD, corresponding to the codes 430-438 of ICD-9 or codes I60-I69 of ICD-10. In addition, the deaths from ill-defined causes (IDC), listed in chapter XVI of ICD-9 and chapter XVIII of ICD-10, as well as the total of all-cause (AC) deaths were used in the analysis. The ICD-9 was in force until 1995, while ICD-10 has been since 1996. The crude and sex- and age-adjusted mortality rates were calculated by use of the direct method¹⁷ per 100,000 inhabitants. The mortality rates from IDC in Rio de Janeiro State have increased significantly since 1990,⁸ thus, compensation was performed, consisting in assigning to deaths from DCS, IHD and CBVD their part of deaths from IDC, corresponding to the fractions observed in the defined deaths, that is, excluded those from IDC. After compensation of the deaths from DCS, IHD and CBVD for those from IDC, sex- and age-adjusted mortality rates were estimated. The standard population for the adjustments was that of Rio de Janeiro State registered

in 2000 by the census, stratified into seven age groups (20-29 years; 30-39 years; 40-49 years; 50-59 years; 60-69 years; 70-79 years; and 80 years or older) for each sex. Those rates were denominated compensated and adjusted.

The mortality rates and GDPpc were correlated by estimating the Pearson coefficients of correlation¹⁸ in all combinations of time series allowed to determine the optimal annual lag, according to the availability of socioeconomic data, which could be 29 years maximally. The optimal annual lag was that with the highest Pearson linear coefficient in all series combined. In addition, the regression slope coefficients were estimated between the dependent variable mortality (DCS, IHD, CBVD) and the independent variable (GDPpc), multiplied by 100 dollars, in series with optimal lag, according to the coefficient of linear correlation.

The quantitative analyses were performed with the Excel-Microsoft¹⁹ and STATA programs.²⁰

Results

The optimal GDPpc time lags (Table 1) with the mortality from DCS group and with the mortality from CBVD subgroup were very close, with respective means of 20.4 and 20.3 years in the Rio de Janeiro State; however, that with the mortality from IHD subgroup was lower, with a mean of 18.1 years. Regarding the regions, the highest time lags were of GDPpc with DCS in the Southern-Central region (mean of 24.3 years), and the lowest, of GDPpc with IHD in the Northern region (mean of 11.5 years). The highest time lag of GDPpc in the municipalities, which was 29 years, the maximum limit allowed by the data available, occurred with DCS in the municipalities of São Pedro da Aldeia, Paraíba do Sul, Vassouras, Nilópolis, São João de Meriti and Niterói; with CBVD, in Cabo Frio, Nilópolis, São João de Meriti and Niterói; and with IHD, in Vassouras, Nilópolis and Niterói. Some municipalities showed no time lag between the variable 'mortality rate' and GDPpc, which occurred with DCS in Porciúncula, with CBVD in Silva Jardim, Miracema and Porciúncula, and with IHD in Saquarema and Sapucaia.

The coefficients of correlation (Table 1) of GDPpc with DCS and CBVD were closer to the extreme value (-1.0), with means of -0.84 and -0.83, respectively; however, the coefficients of correlation of GDPpc with IHD were closer to absence of correlation (0), with mean of -0.62. The most extreme of those coefficients was that with DCS in Niterói (-0.99). Only the municipalities of São Pedro da Aldeia

and Cambuci showed positive coefficients of correlation of GDPpc with IHD, +0.49 and +0.20, respectively, but closer to the level of absence of correlation.

The evolution of the GDPpc in the Rio de Janeiro State municipalities over the past six decades showed a GDPpc elevation with heterogeneous distribution of the mean GDPpc values between the regions and the municipalities (Figure 1). The highest GDPpc values over the years were found in the capital of the Rio de Janeiro State, in Niterói, and in some more industrialized municipalities of inner state, such as Resende and Barra Mansa; and, in the past decade, in the coastal municipalities of the Northern and Coastal Lowlands regions, which concentrate the oil industry.

The death variations at every 100-dollar increment in GDPpc (Figure 2) were higher in the group of deaths from DCS, because that group includes the two subgroups, CBVD and IHD, showing an important mortality reduction related to GDP elevation. Such mortality reduction related to GDPpc elevation was very heterogeneous: there are municipalities where a 100-dollar increment in GDPpc correlated with a reduction by more than 60 deaths from DCS, such as in Cordeiro, a municipality of the Mountain region. However, in only two small municipalities, with less than 40,000 inhabitants aged 20 years or older in 2010, São Pedro da Aldeia and Cambuci, the GDPpc elevation correlated with a mild increase in the number of deaths from IHD. In addition, in four municipalities (Valença, Niterói, Rio de Janeiro and Nova Friburgo), the 100-dollar increment in GDPpc correlated with a higher reduction in deaths from IHD than from CBVD, a pattern that is opposite to those of the other municipalities, where the GDPpc increment correlated with a higher reduction in deaths from CBVD.

Discussion

Reductions in the mortality rates from DCS have been shown in the Rio de Janeiro State municipalities for the past three decades.²¹ In addition, GDPpc elevations have been observed in all municipalities studied (Figure 1) since 1950. They reflect the improvement in the socioeconomic indicators occurring all over Brazil, where the following aspects have been observed: income increase; mortality rate decrease; life expectancy increase; fertility decrease; child mortality reduction; and educational level increase resulting from illiteracy reduction. In addition, the improvement in the indicators in Brazil is also associated with the great income concentration.²²⁻²⁴

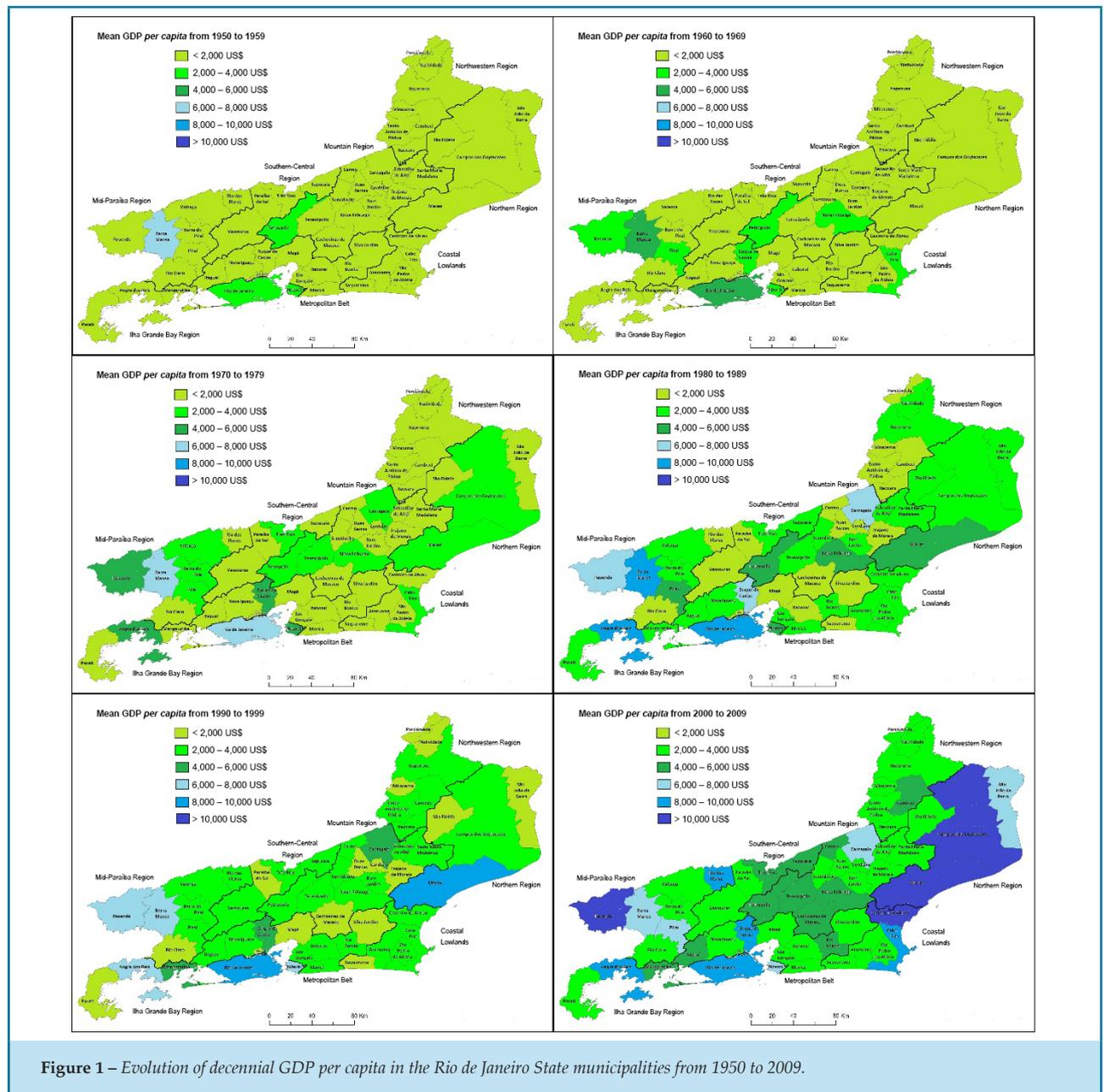
Table 1 – Optimal time lag and Pearson coefficients of correlation between mortality from DCS, CBVD and IHD per 100,000 inhabitants and GDP per capita in the aggregates of the Rio de Janeiro State municipalities from 1979 to 2010

Regions/municipalities	DCS OAL	DCS Correl	CBVD OAL	CBVD Correl	IHD OAL	IHD Correl
Ilha Grande Bay						
Angra	21	-0.90	21	-0.86	23	-0.78
Mangaratiba	21	-0.73	17	-0.68	23	-0.40
Parati	22	-0.77	22	-0.72	21	-0.47
Means	21.3	-0.80	20.0	-0.75	22.3	-0.55
Coastal Lowlands						
Araruama	22	-0.90	22	-0.89	19	-0.31
Cabo Frio	21	-0.85	29	-0.82	20	-0.75
Casimiro	14	-0.83	17	-0.80	14	-0.65
São Pedro da Aldeia	29	-0.76	21	-0.81	12	0.49
Saquarema	24	-0.79	20	-0.68	0	-0.38
Means	22.0	-0.83	21.8	-0.80	13.0	-0.32
Southern-Central Region						
Paraíba do Sul	29	-0.91	25	-0.86	3	-0.69
Sapucaia	16	-0.79	17	-0.81	0	-0.40
Três Rios	23	-0.90	24	-0.85	20	-0.80
Vassouras	29	-0.99	28	-0.97	29	-0.89
Means	24.3	-0.89	23.5	-0.87	13.0	-0.69
Metropolitan Belt						
Duque de Caxias	26	-0.96	26	-0.93	20	-0.89
Itaboraí	6	-0.90	6	-0.85	15	-0.88
Itaguaí	21	-0.93	21	-0.84	20	-0.85
Magé	26	-0.76	26	-0.80	26	-0.58
Maricá	18	-0.93	20	-0.78	18	-0.78
Nilópolis	29	-0.95	29	-0.90	29	-0.90
Nova Iguaçu	26	-0.97	26	-0.96	27	-0.86
Rio Bonito	24	-0.92	25	-0.87	23	-0.69
São Gonçalo	23	-0.98	26	-0.98	20	-0.97
São João de Meriti	29	-0.95	29	-0.91	28	-0.84
Silva Jardim	1	-0.64	0	-0.60	5	-0.32
Means	20.8	-0.90	21.3	-0.86	21.0	-0.78
Mid-Paraíba Region						
Barra do Pirai	23	-0.92	23	-0.93	26	-0.90
Barra Mansa	17	-0.84	17	-0.85	16	-0.83
Pirai	25	-0.72	26	-0.67	26	-0.64
Resende	23	-0.95	23	-0.95	25	-0.87
Rio Claro	26	-0.74	24	-0.73	6	-0.40

Continuation

Rio das Flores	17	-0.70	19	-0.65	16	-0.36
Valença	22	-0.93	21	-0.88	28	-0.87
Means	21.9	-0.83	21.9	-0.81	20.4	-0.69
Niterói						
Niterói	29	-0.99	29	-0.97	29	-0.98
Northwestern Region						
Cambuci	13	-0.82	19	-0.84	18	0.20
Itaocara	21	-0.88	22	-0.91	22	-0.67
Itaperuna	24	-0.89	25	-0.89	24	-0.69
Miracema	3	-0.81	0	-0.79	14	-0.50
Natividade	20	-0.79	22	-0.88	17	-0.72
Porciúncula	0	-0.78	0	-0.66	6	-0.54
Santo Ant de Padua	24	-0.90	25	-0.90	20	-0.92
Means	15.0	-0.84	16.1	-0.84	17.3	-0.55
Northern Region						
Campos	21	-0.89	22	-0.92	28	-0.78
Macaé	5	-0.93	9	-0.93	3	-0.88
São João da Barra	19	-0.76	21	-0.80	12	-0.33
São Fidelis	19	-0.83	20	-0.80	3	-0.40
Means	16.0	-0.85	18.0	-0.86	11.5	-0.60
Rio de Janeiro						
Rio de Janeiro	25	-0.98	25	-0.97	25	-0.95
Mountain Region						
Bom Jardim	17	-0.85	22	-0.90	13	-0.80
Cachoeiras	29	-0.79	29	-0.71	7	-0.25
Cantagalo	21	-0.65	18	-0.67	22	-0.33
Carmo	18	-0.93	19	-0.93	19	-0.54
Cordeiro	28	-0.72	29	-0.79	27	-0.52
Duas Barras	15	-0.67	20	-0.60	13	-0.49
Nova Friburgo	18	-0.92	22	-0.91	17	-0.90
Petrópolis	24	-0.90	22	-0.88	29	-0.91
Santa Maria Madalena	19	-0.72	12	-0.77	25	-0.20
São Sebastião do Alto	17	-0.74	23	-0.88	19	-0.54
Sumidouro	23	-0.70	3	-0.67	17	-0.53
Teresópolis	22	-0.95	23	-0.97	19	-0.86
Trajano de Morais	13	-0.74	6	-0.70	9	-0.38
Means	20.3	-0.79	19.1	-0.80	18.2	-0.56
Means of the Rio de Janeiro State	20.4	-0.84	20.3	-0.83	18.1	-0.62

DCS: diseases of the circulatory system; CBVD: cerebrovascular diseases; IHD: ischemic heart diseases; OAL: optimal annual lag; Correl: coefficient of correlation.



This study was aimed at demonstrating a correlation between the reduction in the mortality rates from DCS and their major subgroups, IHD and CBVD, occurring since 1980, and the improvement in socioeconomic indicators from the second half of the 20th century. Although GDPpc is a good socioeconomic indicator portraying an overview of the socioeconomic conditions of a certain place, it is not the best; however, because the GDP data of the Rio de Janeiro State municipalities are available and organized by municipality since 1920, we chose to correlate them with those mortality rates, considering the several time lags between those indices.¹³

In the period analyzed, from 1950 to 2010, the GDPpc increased in all municipalities, but heterogeneously. The highest GDPpc values were found in the municipalities of Rio de Janeiro and Niterói, the former is the current state capital, former capital of Brazil from 1763 to 1960²⁵ and of the extinct Guanabara State until 1975, while the latter was the former capital of the Rio de Janeiro State until 1975.²⁶ Other municipalities had high GDPpc, being directly related to certain industrial activities as follows: Barra Mansa, related to the steelworks industry (Volta Redonda, which houses the headquarters of the Brazilian Steelworks Company, was aggregated to Barra Mansa

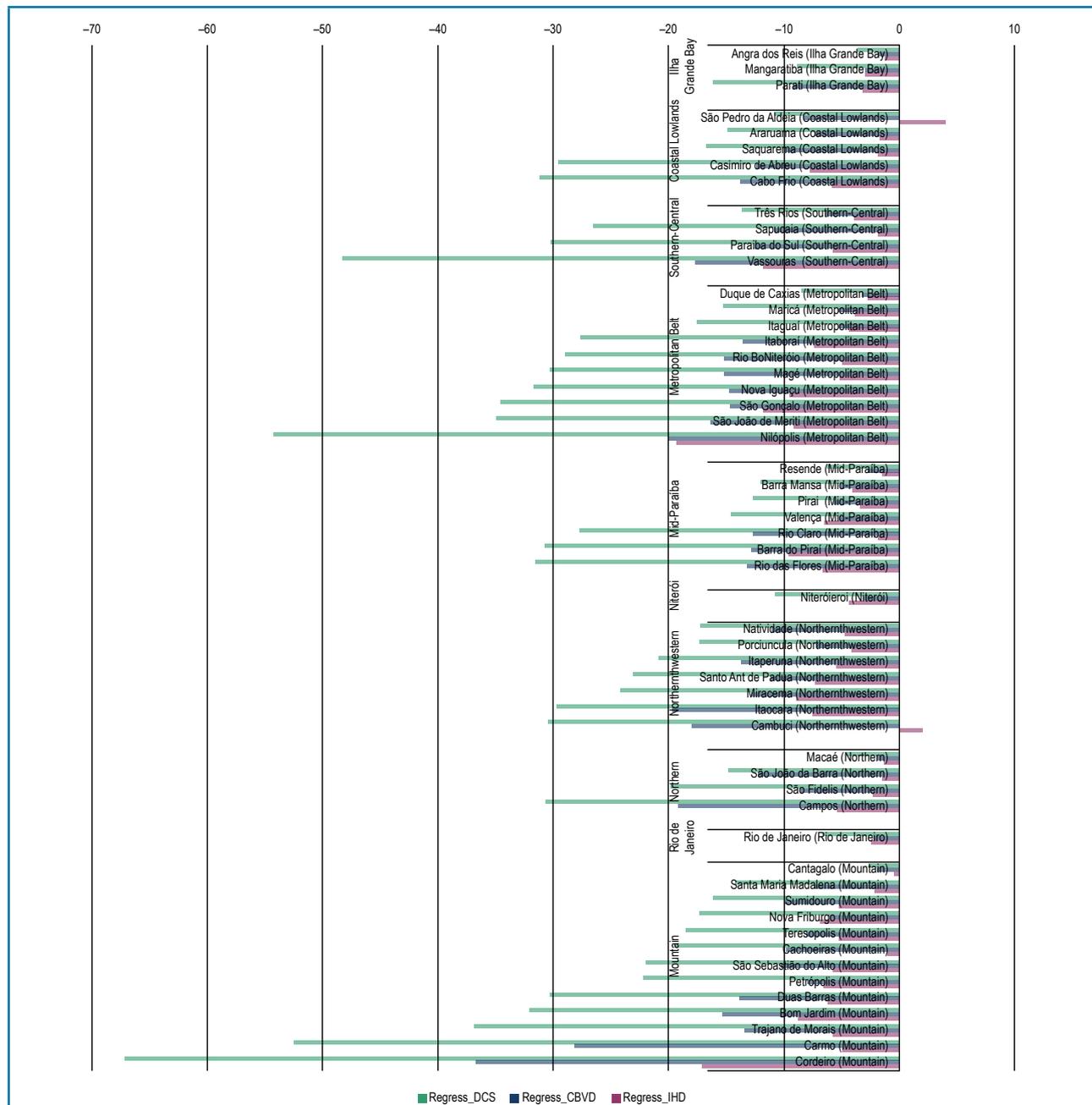


Figure 2 – Variations (linear regression model) in the deaths from diseases of the circulatory system (DCS), cerebrovascular diseases (CBVD) and ischemic heart diseases (IHD) per 100,000 inhabitants at each 100-dollar increment in the GDP per capita in the aggregates of the Rio de Janeiro State municipalities from 1979 to 2010.

because it was emancipated only in 1955²⁷); Angra dos Reis, related to the naval industry; Resende, related to the automotive industry; and municipalities related to the oil industry, such as Duque de Caxias, Macaé, Campos dos Goytacazes, Casimiro de Abreu, Cabo Frio and São João da Barra.²⁸ However, the big GDPpc increase of those municipalities occurred only in the last years of the study,

probably not correlating with the reduction in deaths from DCS, whose influence might be felt in future years.

We demonstrated that the mean coefficient of correlation between GDPpc elevation since 1950 and mortality from DCS in adults since 1979, with a time lag of a little more than 20 years, of all Rio de Janeiro State municipalities was negative and high (-0.84).

Being negative indicates an inverse relationship, that is, the higher the GDPpc, the lower the mortality from DCS. This evidences that the improvement in the socioeconomic indicators preceded the reduction in cardiovascular deaths. The behavior of the CBVD subgroup was similar to that of the DCS, regarding both the correlation index of GDPpc and the time lag. Regarding the IHD subgroup, the correlation indices, although significant, were not that close to the negative maximum value, and the optimal time lag was also a little shorter, around 18 years. These differences in IHD as compared to DCS and CBVD might be due to the lowest mortality rates from IHD in almost all municipalities throughout the study period.²¹ This might have caused greater fluctuations in the IHD rates than in the others, which is even more evident when we observe that the municipalities with smaller populations have the lowest correlation indices and the greatest variations in optimal time lag.

The increase in GDPpc might have influenced on the reduction of the deaths from DCS. This impact varied in the different Rio de Janeiro State municipalities, in the Rio de Janeiro State regions, and even in the municipalities within the same region. In some municipalities, such as Carmo and Cordeiro in the Mountain region, and Nilópolis in the Metropolitan Belt, the 100-dollar increment in GDPpc was related to a reduction of more than 50 deaths per year from DCS. In other municipalities, however, such as Angra dos Reis in the Ilha Grande Bay region, Macaé in the Northern region, and Cantagalo in the Mountain region, that same increment in GDPpc related to a reduction of less than 10 deaths per year from DCS. In two of those municipalities, that phenomenon can be explained by the great elevation in the GDPpc of Macaé and Angra dos Reis in the study period, because, despite having a reduction in death from DCS similar to that of other municipalities, their great elevation in GDPpc made the variation in deaths as compared to the GDPpc increase smaller. The CBVD as compared to the IHD stand out as the group with the highest reduction in the number of deaths per year, although the higher mortality rates from CBVD in the initial years of the study should be considered. In addition, one can infer that the costs to prevent and reduce mortality from CBVD are lower than those estimated for IHD, because the reduction in the incidence of stroke, the major cause of death from CBVD, is closely related to the improvement in primary health care and arterial hypertension control, conditions affected by the global economic improvement reflected in

GDP increase.²⁹⁻³¹ By providing important details when analyzing the Rio de Janeiro State municipalities, this study corroborates the clear inverse relationship between cardiovascular mortality rates and GDPpc. The inverse relationship of those variables has been suggested in the study³² relating the Brazilian GDPpc between 1947 and 2004 to the mortality from IHD in the Rio de Janeiro State between 1980 and 2002, also showing the time lag between those variables. In addition, the use of the Human Development Index (HDI) showed an inverse relationship with the mortality rates from CBVD in the administrative regions of the Rio de Janeiro municipality, and to every 0.05 reduction in the HDI, there was a 65% increase in the number of deaths from CBVD.³³

One limitation of this study is the quality variation in the completion of death certificate over time and in the municipalities studied. However, death certificates are the best mortality data source available. A more serious limitation was the difficulty to obtain the economic data of the years before 1980, because they sometimes had a decennial periodicity and only those of the years of the IBGE census could be found, which determined the use of interpolation for the unavailable years. The compensation of the number of deaths from DCS, CBVD and IHD considering the deaths from IDC might have caused inaccuracy in the estimated mortality rates. Another limitation is the analysis with possible maximal time lag of 29 years, because, in some municipalities, the optimal time lag coincided with that value, and, thus, the actual value might have been greater; however, that happened in only 5 of 56 municipalities.

Conclusion

From 1979 to 2010, there was an important reduction in mortality from DCS in the Rio de Janeiro State municipalities, especially in the CBVD subgroup. The decrease in mortality from DCS was preceded by periods of GDPpc elevation, and the evolutionary variation of that indicator showed an important correlation with the reduction in mortality. A regional pattern for that correlation that indicated the importance of improving the population life conditions to reduce cardiovascular mortality could not be identified.

Author contributions

Conception and design of the research: Soares GP, Klein CR, Souza e Silva NA, Oliveira GMM. Acquisition of

data: Soares GP, Klein CR, Souza e Silva NA, Oliveira GMM. Analysis and interpretation of the data: Soares GP, Klein CR, Souza e Silva NA, Oliveira GMM. Statistical analysis: Soares GP, Klein CR, Souza e Silva NA, Oliveira GMM. Writing of the manuscript: Soares GP, Klein CR, Souza e Silva NA, Oliveira GMM. Critical revision of the manuscript for intellectual content: Soares GP, Klein CR, Souza e Silva NA, Oliveira GMM.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Sources of Funding

There were no external funding sources for this study.

Study Association

This article is part of the thesis of Doctoral submitted by Gabriel Porto Soares, from Universidade Federal do Rio de Janeiro.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

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