Original Article

# Premature Mortality due to Cardiovascular Disease and Social Inequalities in Porto Alegre: from Evidence to Action

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## Summary

**Background: Two perspectives, the economic (disease causing impoverishment) and social (poverty causing illness), have internationally disputed the justification for public health policies.**

**Objective: To investigate the relationship between early mortality by cardiovascular disease (CVD) and socioeconomic (SE) conditions in the city of Porto Alegre (PA), and discuss bases and strategies for the prevention of CVD.**

**Methods: An ecological analysis of the association between mortality by CVD at 45-64 years of age and SE conditions of 73 districts/neighborhoods in PA. The relative risk (RR) and the fraction of risk (FRA) attributable to inequality among the districts grouped into 4 SE strata were estimated.**

**Results: Early mortality by CVD was 2.6 times higher in the districts classified in the worst compared to the best of the 4 SE strata. Among the extreme districts, the RR reached 3.3 for CVD and 3.9 for cerebrovascular disease. Compared to the mortality in the best stratum, 62% of the early deaths in the worst stratum and 45% of those in the city as a whole could be attributed to socioeconomic inequality.**

**Conclusion: Almost half of the mortality by CVD before 65 years of age can be attributed to poverty. Disease, on the other hand, contributes towards poverty and reduces competitiveness of the country. It is necessary to reduce illness and recover the health of the poorest inhabitants with investments that result in national economic development and improvement of the social conditions of the population. (Arq Bras Cardiol 2008; 90(6): 370-379)**

**Key words: Mortality; cardiovascular diseases; disease prevention; social inequity.**

## Introduction

Two perspectives, the macroeconomic (disease causing impoverishment)[1] and the social (poverty causing disease)[2-4], have been disputed as justifications for public health policies.

In the area of chronic diseases, as of 2001, international organizations have alerted to the risk of migration of the CVD epidemic from central countries to those of middle and low incomes due to populational aging, urbanization, and the increased capacity for consumption of the inhabitants of these countries[5-7]. To prevent these chronic illnesses, they have recommended restructuring health care services in order to prioritize the early identification of individuals at risk and their ongoing treatment[5-7].

The macroeconomic argument has been emphatically used to stimulate immediate action. Based on demographic estimates, Leeder et al[1] suggest that there is a two-decade window of opportunity to establish awareness and avoid catastrophic consequences for countries twenty to forty years from now.

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The perspective of social determinants in illness had little expression in the central countries during the 20th century, and reemerged during the transition to the 21st century because of economic globalization[8]. Nevertheless, attention given to chronic diseases in this agenda is still irrelevant[9].

This study intends to investigate the association between early mortality by cardiovascular disease and socioeconomic inequalities in Porto Alegre, and suggest paths to prevention based on the interpretation of the findings.

## Methods

This is a cross-section ecological study, which has as analysis units the districts of the Porto Alegre municipality. The city was chosen because of its high average Human Development Index (HDI = 0.865 in 2000[10]) despite marked inequalities in social development indicators (from 0.46 to 0.93) among its regions[11].

Data relative to the variables "age", "gender", "basic cause of death (ICD10)", and "place of residence" were extracted from a databank with 51,562 georeferenced deaths during the period between 2000 and 2004, the number of liveborns in the information system of liveborns in Porto Alegre from 2000 to 2004, and information relative to demographic and socioeconomic variables of microdata from the year 2000

Census. Based on the available primary variables, those used in this study and listed in Panel 1 were selected or constructed. The decision to use early deaths instead of all deaths was made in order to increase the specificity of cardiovascular diagnoses and to avoid the possibility of the greater longevity of the richest individuals artificially inflating the risk of death by cardiovascular disease in this population stratum.

All data were pooled by district of residence. Data relative to all the original 9 districts with less than 3,000 inhabitants in 2000 were incorporated into contiguous districts, resulting in a universe of 73 study units.

In order to minimize random fluctuation in the estimates of annual mortality by CVD, ischemic heart disease (IHD), and cerebrovascular disease (CeVD) in the district, in addition to the mean 5-year mortality rate, empirical Bayesian attenuation was used. Assuming the existence of a spatial tendency in event distribution, the occurrences were reestimated taking into consideration the annual means of cases in the neighboring districts.

Analyses were carried out using as units the districts and their distribution in 4 SE risk strata. Initially, mortality cartograms were made stratifying the districts into 4 levels of each of the seven socioeconomic variables selected (Fig. 1). The cartograms suggested a strong spatial correlation among the independent variables.

In order to optimize stratification as per the set of independent variables, 3 different strategies were used: cluster analysis, analysis of the principal components, and Moran spatial autocorrelation. The cluster analysis defined, for the set of variables, four strata as the groupings with the least variability within each one and the greatest difference among them. The distribution of the districts in the strata defined by the K-means method is shown on Figure 2A. Analysis of the principal components sought to reduce the number of independent variables (due to the high spatial autocorrelation suggested by the initial cartogram) prior to the stratification of the districts. The technique resulted in the production of a single component, with the power to explain 74% of the variation among the study units and highly correlated with all the variables. This component was parameterized in order to be read as a score with a mean equal to zero and standard deviation equal to one, in which the more negative values were associated with the better districts and the more positive values with the worst districts. Stratification of the districts in four levels according to this score can be seen on the cartogram in Figure 2B. This score was also used to estimate the difference in risk and the relative risk among the extreme districts (see below). For Moran's autocorrelation, a matrix of adjacent neighborhoods was used. Each one of the independent variables was tested and the score was generated by the analysis of the principal components. The objective was to assess if the neighboring areas are similar regarding the variable in question compared to the standard that would be expected in a situation of complete spatial randomness. The autocorrelation was considered significant when $p<0.05$. The Moran I Global Indices consistently showed highly significant global spatial autocorrelation for all the independent variables and for the principal component. The Moran I Local Indices enabled mapping of the districts according to whether they were surrounded by neighborhoods with equivalent (low-low or high-high) or different (low-high or high-low) rates of risk, guiding the delimitation of borders among the strata. The splatter plot for the score generated in the principal component analysis may be seen in Figure 2C. The final district SE stratification proposal took into account the coincidences among the three methods and the borders established by Moran's method. In the few cases with unclear district classification, reference was made to the original cartograms of the education and income variables, and personal knowledge of the city was used. The final stratification of the districts into strata 1, 2, 3, and 4, respectively, as high, medium-high, medium-low, and low socioeconomic levels is presented in Figure 2D.

The 4 strata reflect approximate quartiles of the quality of life levels into which the districts are distributed. Based on them, estimates were made of the relative risk (RR) and fraction of risk (FRA) of early cardiovascular death attributable to SE inequality between stratum 1 (best) and 4 (worst) SE level, and between stratum 1 and the city as a whole.

**Panel 1 - Variables used in the analyses**

| | |
|---|---|
| **Independent variables (Socioeconomic)** | |
| Education | Average number of years of schooling of the head of the household |
| Income | Proportion of domiciles where the head of the household has a monthly income of more than 10 times the minimum monthly wage |
| Population density | Proportion of domiciles with 6 or more residents |
| External causes (chap. XIX ICD10) | Mortality rate by external causes, adjusted for age and gender, per 100,000 inhabitants |
| Aging | Aging rate: >60*100/<16 |
| Fertility | General fertility rate: liveborns/1,000 women 15-49 years of age |
| Child mortality | Child mortality rate: deaths < 1 year/ liveborns |
| **Dependent variables (Coefficients of mortality p/100,000 inhabitants 45-64 (ICD) years of age)** | |
| Cardiovascular disease (I00-I99) | Mortality rate due to cardiovascular disease in the 45-64 years age bracket, adjusted for age and gender |
| Ischemic heart disease (I20-I25) | Mortality rate due to ischemic heart disease in the 45-64 years age bracket, adjusted for age and gender |
| Cerebrovascular disease (I60-I69) | Mortality rate due to cerebrovascular disease in the 45-64 years age bracket, adjusted for age and gender |

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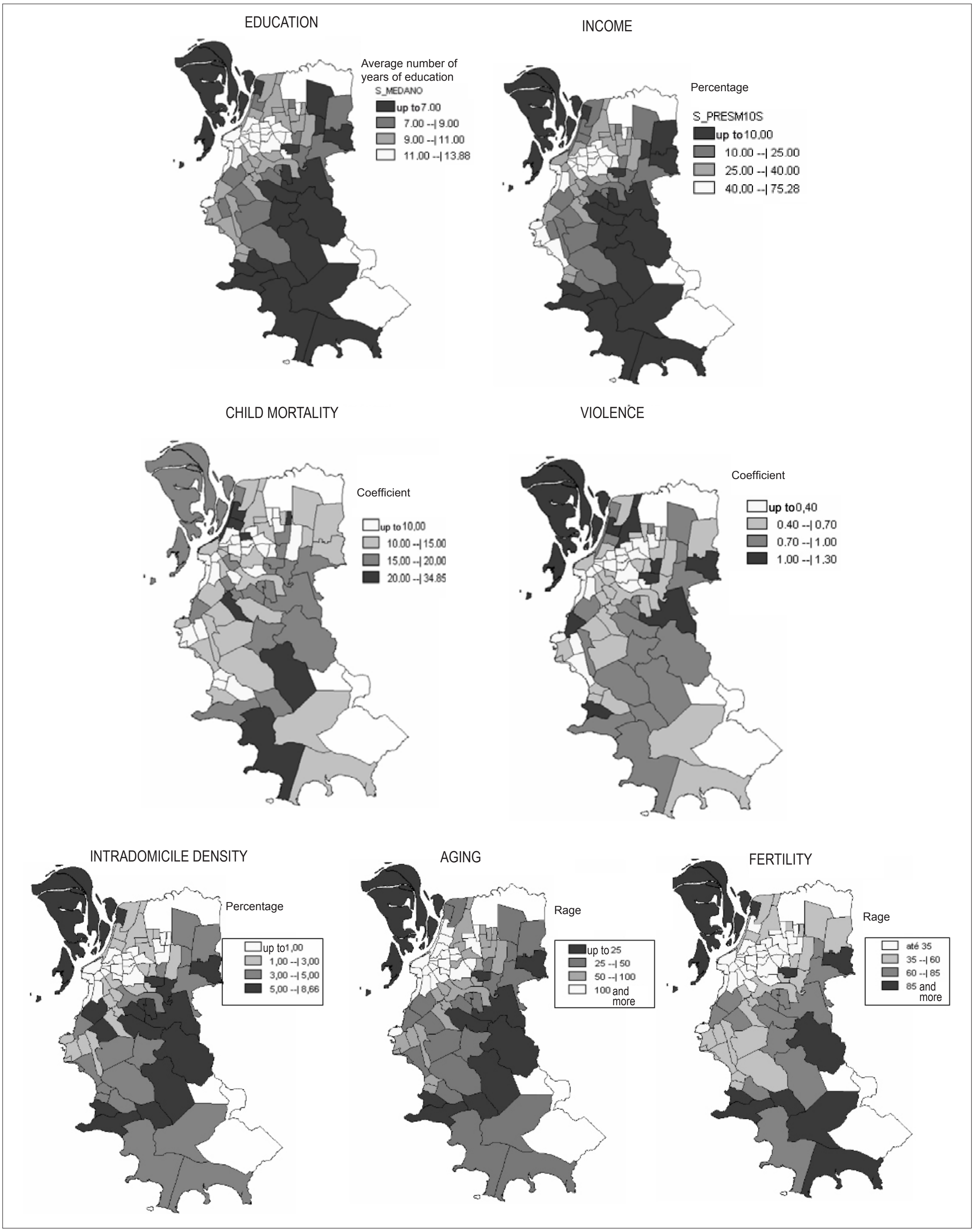


*Figure 1 - Cartograms of the districts of the municipality of Porto Alegre with the distribution of the independent variables* that represent the dimensions of educational level, income, intradomicile density, aging, and fertility in 2000 and violence and child mortality in 2000-2004*; Educational level - average number of years of education of the head of the household; Income - % of domiciles where the head of the household has a monthly income >10 times the monthly minimum wage; Child Mortality - Coefficient of Child Mortality; Violence - Coefficient of Mortality by External Causes; Intradomicile density - % of domiciles with 6 or + residents; Aging - aging rate; Fertility - fertility rate.*

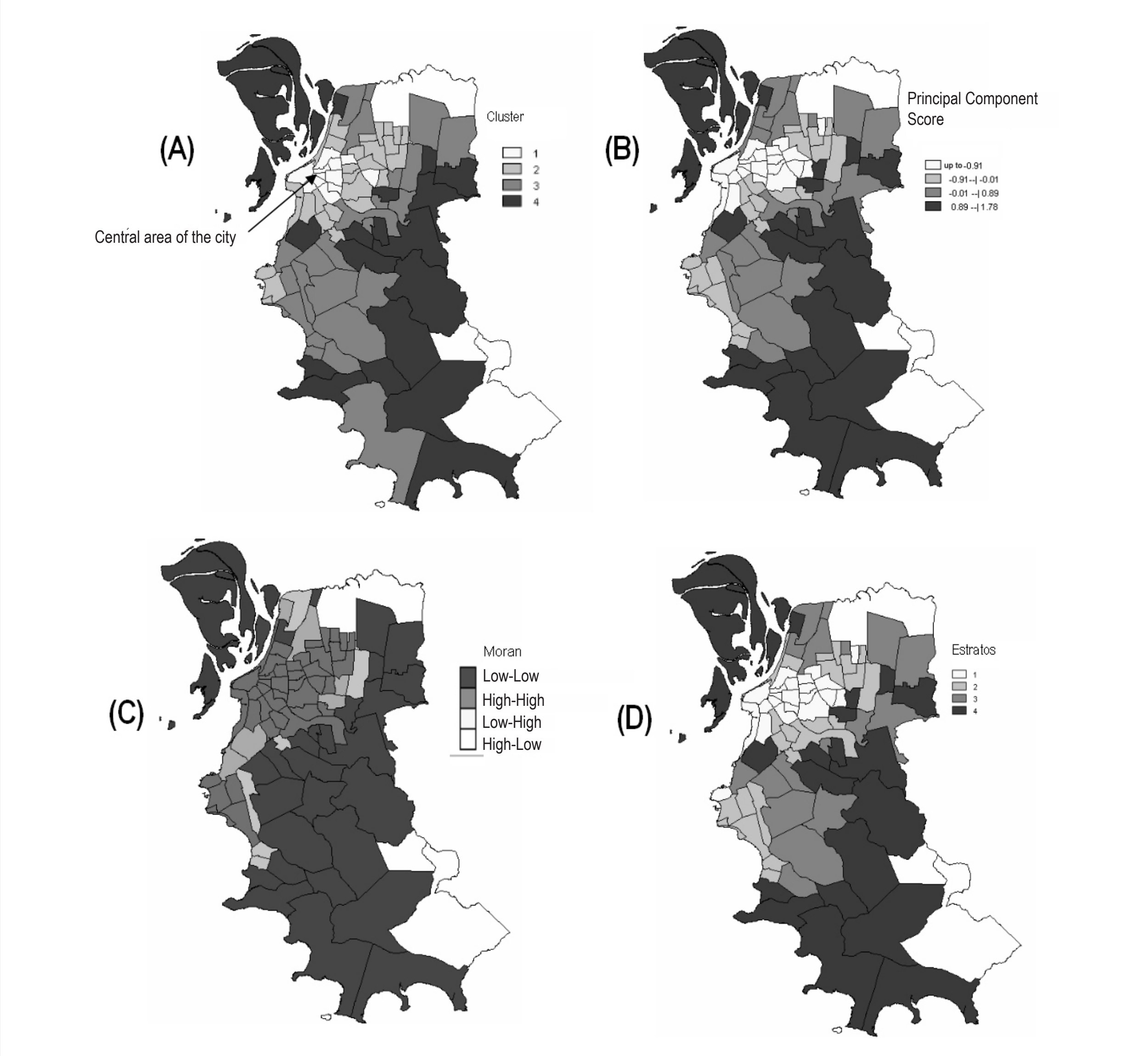


*Figure 2 - Cartogram of Porto Alegre with identification of the districts according to strata resulting from the Cluster Analysis (A), scores from the Analysis of the Principal Components (B), types of Moran local spatial associations using scores of the Analysis of the Principal Components (C), and final strata, after consideration of the previous analyses (D).*

With data referring to each district, a matrix was produced to correlate all the variables. In order to summarize the association between the SE condition of the district and early mortality by CVD, IHD, and CeVD, multiple linear regression analyses were performed. There was a spatial correlation among the independent variables and among the dependent variables, but not in the associations among them, i.e., the association in one district occurred independently from the association in the neighboring districts. Thus, there is no need to report spatial regression techniques (carried out with similar findings).

In order to describe early CVD mortality inequality among the districts with extreme SE conditions, the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII) were estimated. Calculation of these estimates requires the creation of an intermediate variable (Ridit), an indicator of the position of mortality relative to the socioeconomic variable, which in this case was the score of the principal component previously described. The districts were ordered according to their SE scores. Next, calculations were made of the Relative Frequency (RF) and Cumulative Frequency (CF) of early deaths weighted by the size of the population, followed by the Ridit = (CF + (CF-RF))/2. SII is the linear regression coefficient of the coefficient of mortality over the Ridit, and RII is the difference between the extreme values of the regression line.

Excel software was used to organize the databank: SPSS 13.0 for Windows and Statistica for non-spatial analyses, GeoDa and SigEpi for spatial analyses, Tabwin for thematic maps, and Brechas 1.0 for measurements of inequalities among the districts. The project was approved by the Ethics

Committee of the *Hospital Moinhos de Vento*, where it was based. The study was partially financed by the Initiative for Cardiovascular Health, CDC-Delhi.

## Results

Between 2000 and 2004, mortality by CVD for 45-64 years of age corresponded to 28.5% of the total deaths and 22.8% of all deaths by CVD. In this age bracket, 40% of the cardiovascular deaths were due to IHD and 30% were due to cerebrovascular disease (CeVD).

Table 1 shows the number of districts, populations, and means of the independent and dependent variables per socioeconomic stratum. There is a linear gradient in the measurements of the independent variables between the best stratum (stratum 1) and the worst stratum (stratum 4). There is also a linear tendency towards increased cardiovascular mortality between stratum 1 and stratum 4. The consistency of the data enables an easy and direct interpretation of these results.

Figure 3 shows the distribution of early mortality by CVD, IHD, and CeVD in the four strata, and figure 4 illustrates the inequalities among the strata. Early mortality by cardiovascular disease is 2.6 times greater in stratum 4 compared to stratum 1. For the stratum with the worst indicators and for the city as a whole, the fractions of mortality (FRA) attributable to social inequality using as reference stratum 1 were 62% and 44.7%, respectively. In other words, 62% of early deaths by CVD in stratum 4 and 44.7% in the city could have been avoided if the respective population had the same socioeconomic conditions as stratum 1. For IHD and CeVD, the fractions of risk attributable to SE inequality were 39.8 and 47.6%, respectively.

The matrix of correlations in figure 5 suggests a high linear-type correlation between the variables. The independent variables that showed the most pronounced relationship with the cardiovascular mortality indicators were *income*, *education,* and *violence*. In the multiple linear regression analysis, *violence and income* remained independent and significantly associated with the three outcomes analyzed. The final mathematical model, considering all the districts and mortality by all CVD, was *Cardiovascular Mortality 45-64 years* = 233.77 + 184.79 *Violence* - 2.6 *Income*

The coefficient of determination ($r^2$) resulting from this equation is 0.61, i.e., 61% of the variability in the distribution of the coefficient of early mortality by CVD can be explained by the variability in the distribution of *Violence* and *Income*. Equivalent findings were noted for the outcomes IHD and CeVD.

The estimated risk of mortality by early CVD in the district with the best socioeconomic situation (corresponding to one Ridit = 1) was 123.1/100,000, and in the district with the worst situation (Ridit = 0) it was 402.5/100,000. The estimated difference (SII) was -279.5/100,000 and the Relative Inequality Index (RII) between the extremes corresponded to 402.5/123.1, or 3.3. In other words, mortality by cardiovascular disease is 3.3 times greater in the worst district relative to the best district. RII was 2.5 for ischemic heart disease, and 3.9 for cerebrovascular disease (Figure 6).

## Discussion

As is true for the United States and Europe, since 1980, mortality rates (deaths/100 thousand inhabitants) due to IHD and cerebrovascular disease dropped significantly in Brazil, for all age groups[12-13]. Even so, the demand for treatment of chronic diseases at health care centers is expected to climb in the next decades, accompanying the dislocation of cohorts born during the period of highest fertility rates (up until approximately 1965-70)[14]. Until 2020, the greatest growth in number of adults will occur

Table 1 - **Number of districts, population, and means of dependent and independent variables** in the socioeconomic strata of Porto Alegre**

| Socio-economic Stratum* | 1. High | 2. Med-high | 3. Med-low | 4. Low | All |
|---|---|---|---|---|---|
| No. of districts | 20 | 20 | 16 | 17 | 73 |
| Population | 278.213 | 312.009 | 397.711 | 370.451 | 1.358.384 |
| Population 45-64 years of age | 67.011 | 69.486 | 73.327 | 57.733 | 267.557 |
| Educational level | 12.5 | 10.0 | 8.1 | 6.2 | 9.4 |
| Income | 56.0 | 30.8 | 16.6 | 6.2 | 28.9 |
| Child mortality | 7.97 | 11.54 | 13.94 | 16.98 | 12.35 |
| Violence | 0.38 | 0.51 | 0.78 | 0.88 | 0.62 |
| Intradomicile density | 0.74 | 1.96 | 3.76 | 6.06 | 2.98 |
| Aging | 138.8 | 81.4 | 45.7 | 25.8 | 76.4 |
| Fertility | 26.8 | 37.8 | 56.3 | 83.6 | 49.5 |
| Coefficient of mortality due to cardiovascular disease | 148.5 | 241.1 | 321.9 | 390.9 | 268.3 |
| Coefficient of mortality due to ischemic heart disease | 73.3 | 111.5 | 156.2 | 158.3 | 121.8 |
| Coefficient of mortality due to cerebrovascular disease | 41.0 | 65.9 | 94.6 | 121.5 | 78.3 |

*** Educational level - average number of years of schooling of the head of the household; Income - % of domiciles where the head of the household has a monthly income > 10 times the monthly minimum wage; Child Mortality - Coefficient of Child Mortality; Violence - Coefficient of Mortality due to External Causes; Intradomicile density - % of domiciles with 6 or + residents; Aging - Aging rate; Fertility - Fertility rate; ** Kruskal Wallis Test - p<0.001 (all variables).*

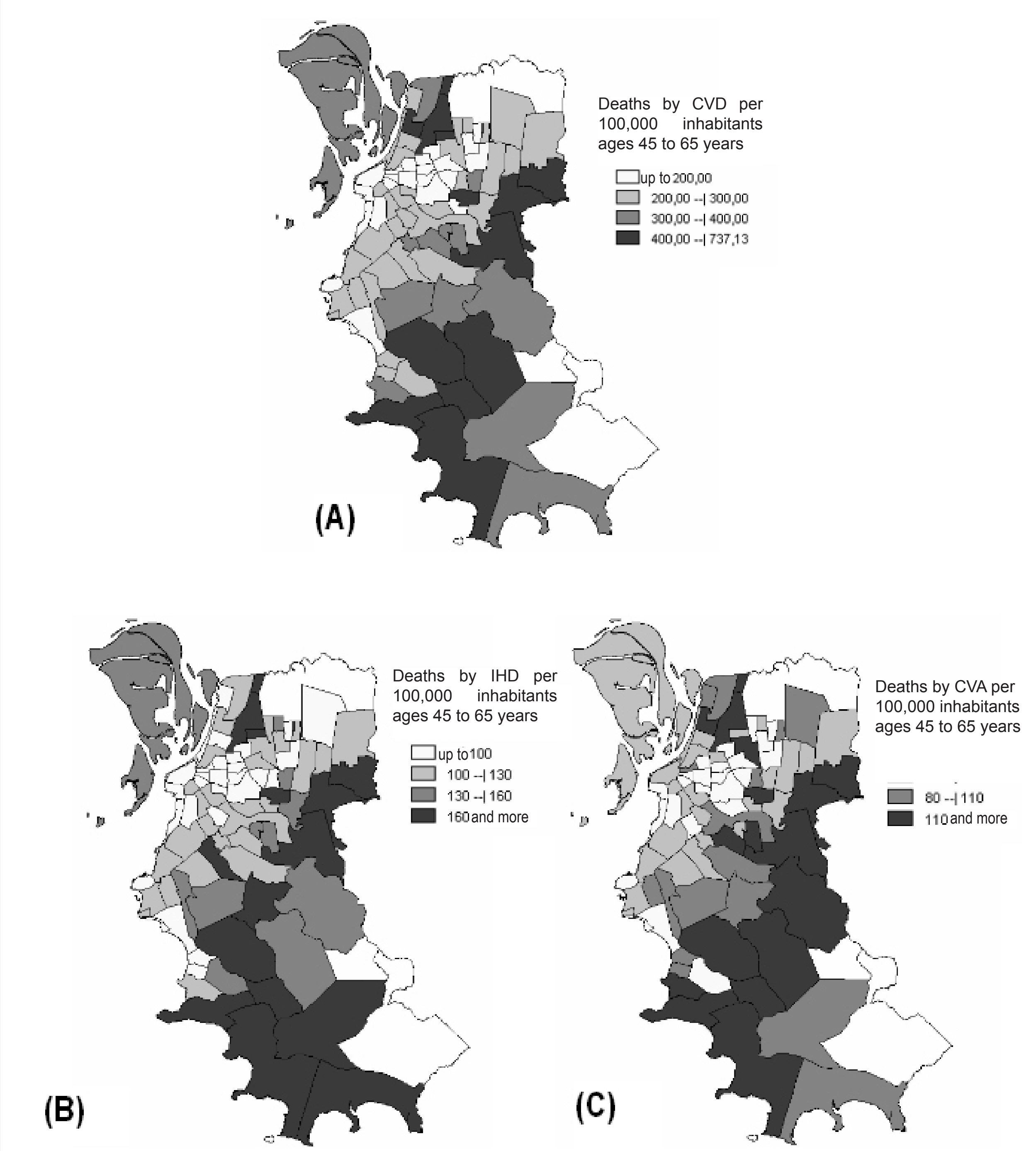


*Figure 3 - Distribution of the districts of Porto Alegre - RS, according to Coefficients of Mortality by Cardiovascular Disease (A), by Ischemic Heart Disease (B), and by Cerebrovascular Disease (C), in the 45 - 65 years age bracket, adjusted for age and gender*, 2000-2004; Sources: IBGE and SIM * Post Bayesian attenuation.*

between the ages of 45 and 64 years. After 2020, growth will shift progressively towards the older population[14]. Mortality by CVD in the 45-64 years of age population is high in Brazil compared to developed countries, especially among the women[15-16]. This difference increases with the decrease in age. In the younger group, aged 35 to 44 years, mortality by acute myocardial infarct and cerebrovascular disease in 1988 was 3 and 5 times higher, respectively, in Brazil than in the USA among men and 4 and 6 times higher, respectively, among women[16]. The findings of this study support the idea that this difference is associated with the poor quality of life of the populations in the large urban centers compared to those of developed countries.

Even in a city with a relatively high HDI such as Porto Alegre,

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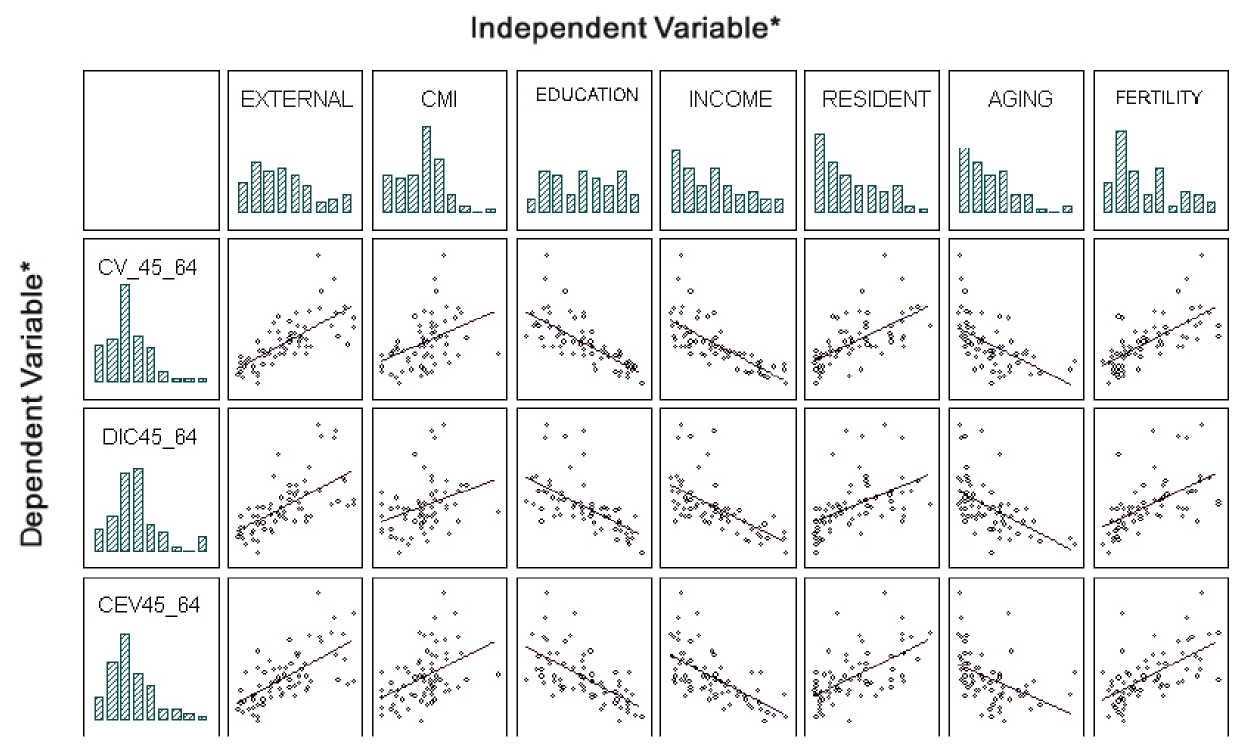
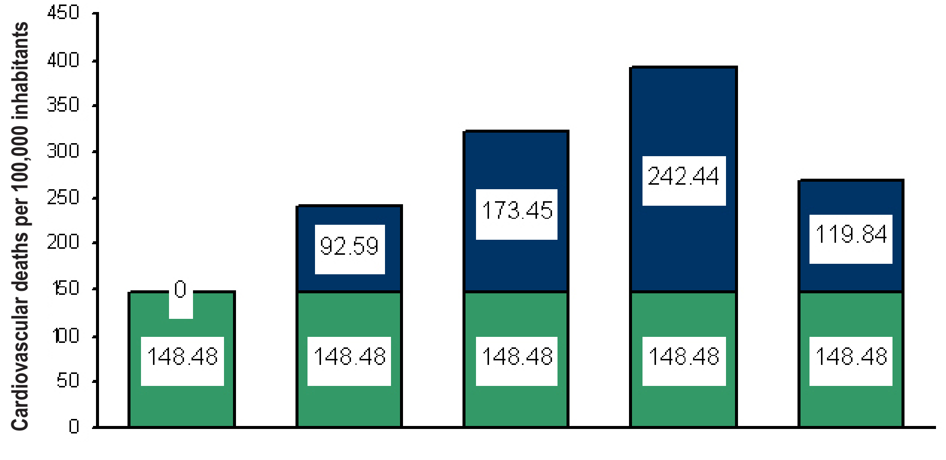



*Figure 4 - Matrix of pearson's correlations and dispersion diagrams among dependent and independent variables* External [Externas] - Coefficient of mortality by external causes; CMI - Child mortality coefficient; Education [educação] - Average number of years of education of the head of the household; Income [renda] - Proportion of domiciles where the head of the household earns 10X the minimum monthly wage or more; Resident [morador] - Proportion of domiciles with 6 or more residents; Aging [envelheci] - Aging Rate; Fertility [fecundid] - Fertility Rate; CV45_64 - Coefficient of mortality by cardiovascular disease; DIC45-64 - Coefficient of mortality by ischemic heart disease; CEV45_64 - Coefficient of mortality by cerebrovascular disease.*




| Stratum | 1 | 2 | 3 | 4 | All |
|---|---|---|---|---|---|
| Relative Risk [95% Confidence Interval] | 1 | 1.62 [1.28 – 2.10] | 2.17 [1.72 – 2.75] | 2.63 [1.09 – 3.35] | 1.81 [1.47 – 2.24] |
| Attributable risk | - | 92.59 | 173.45 | 242.44 | 119.84 |
| Fraction of attributable risk (%) | - | 38.41 | 53.73 | 62.02 | 44.66 |
| Annual No. of attributable deaths | - | 64 | 126 | 140 | 322 |

*Figure 5 - Coefficient of Mortality due to cardiovascular disease for 45-64 years age bracket, relative risk, attributable risk, fraction of attributable risk, and annual number of attributable deaths, as per socioeconomic strata. Porto Alegre, 2000-2004.*

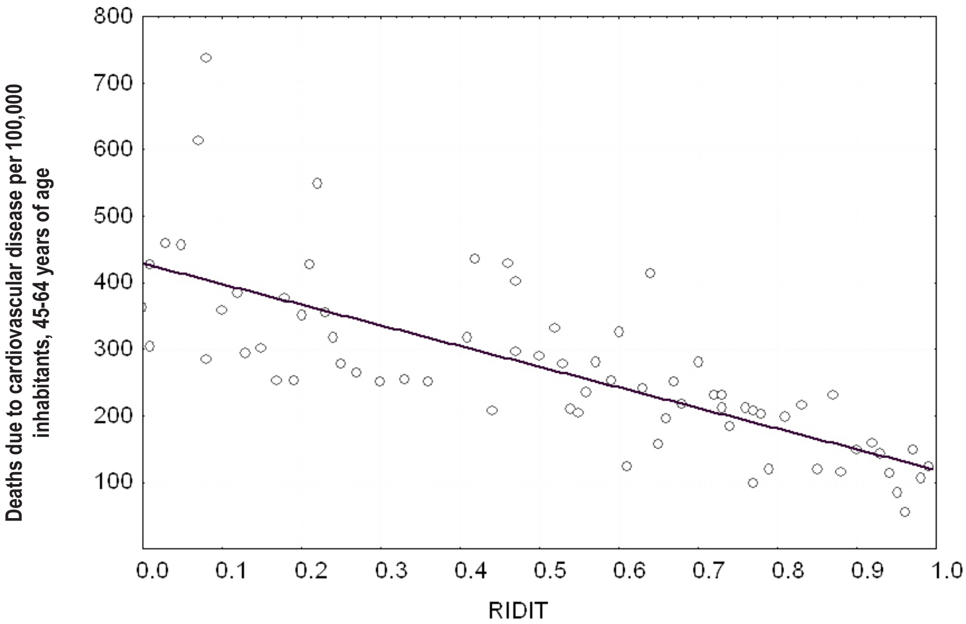



*Figure 6 - Dispersion diagram and simple linear regression line of the Coefficient of Mortality due to cardiovascular disease for 45-64 years of age on the RIDIT variable*, Porto Alegre, 2000-2004* Ridit - Indicator of accumulated relative rank position of each observational unit relative to an ordered socioeconomic variable, which in this case is the score of the Principal Component.*

almost half of the early deaths (45%) could be avoided if all the districts had the best conditions of the 4 SE strata, which means *80% of the excessive early deaths in the city* attributable to this inequality of socioeconomic conditions among districts. Two variables, the average of years of education of the household heads - an indicator of the *antecedents* of social inclusion/exclusion of the residents - and mortality by external causes - an indicator of the *current exposure* to risk, were capable of together explaining 61% of the distribution of mortality by CVD among the districts.

These findings are consistent with others published recently in Brazil[17-19]. Ishitani et al[17] in studying the deaths of adults 35-64 years old between 1999 and 2001 in 98 municipalities with more than 100,000 inhabitants, 90% of them residents of the urban area, showed, by simple and multiple linear regression, a negative correlation between CVD and income/educational level, and a positive association with poverty and poor living conditions. In São José do Rio Preto, SP, Godoy et al[18] showed that the principal component extracted from the variables that reflects income and education in the domiciles explained 87% of the variation among the census strata, and stratification in quartiles based on this component was associated with a mortality by CVD 40% higher in the worst compared to the best stratum. Melo et al[19] in studying the spatial distribution of mortality by acute myocardial infarct in Rio de Janeiro, described a spatial distribution associated with a strong socioeconomic gradient.

Differences in the occurrence of illness and death may be attributed to differences in access to treatment of patients[20] and the difference in exposure to risk factors[1,21,22]. Similarly, intervention proposals emphasize the amplification of investments in health care services geared towards early identification and ongoing accompaniment of individuals with chronic diseases and their risk factors[23]. Nevertheless, individual treatment of ill or high-risk patients, while fulfilling an important humanitarian role, has a small impact in reducing populational rates of illness, since action is taken in reference to the cause of those cases, but not to the cause of the occurrences[24].

Nancy Krieger has proposed that social inequality in health care is the result of an embodiment of unequal social experiences - embodying inequality[25]. Among the conditions biologically incorporated but with strong social determinants are birth weight, height, and immune responses to acquired infections[25], which are known to be associated with the acquisition of metabolic and immune phenotypes of risk for some causes of illness[26]. In the case of atherosclerosis, the transition from the degenerative to the inflammatory paradigm[27] would enable these SE differences in the occurrence of CVD to be attributed to the interaction between unequal accumulation of biological vulnerability over a lifetime (low birth weight, infections, and stress) and unequal levels of current exposure to environmental factors[26,28]. Investment in prevention, in this case, would be an investment in the improvement of living conditions of the population.

Even though history never repeats itself, much can be learned from it. There are significant coincidences between the present situation of the large Brazilian cities and European cities at the beginning of the 19th century[29-32]. As is the case here, industrialization promoted a rapid increase in the urban population with the appearance of shanty towns/slums and great social inequality in mortality[30-31]. During the 100 years of the industrial revolution, the population of Paris and London increased 5 times, and that of Berlin, 10 times[31]. In 50 years, between 1950 and 2000, the Brazilian urban population went from 19 million to 146 million inhabitants, i.e., it increased more than 7 times[33]. Between 1830 and 1840, Villermé in France and Chadwick in England showed that mortality was greater in the large cities. Villermé showed that mortality was 50% higher in the poorest districts[31]. Tuberculosis, followed closely by pneumonia and influenza, was the primary cause of death in European cities[31]. The question debated then was if poverty caused disease or disease caused poverty[29-32]. The interrelationship between disease and social development was so significant in Europe that the famous phrase spoken by Virchow dates back to this period (1848): *"Medicine is a social science, and politics is nothing more than medicine on a large scale."* Also in 1948, after documenting the horrific health conditions of the working population in Great Britain, Edwin Chadwick – the father of English Health Care[32] - defended and promoted the approval of the "Public Health Act." Chadwick's argument was that generalized disease resulted in poverty for the workers and a significant loss of economic productivity for England. The solution he proposed was to carry out investments in sanitary engineering projects, which besides benefiting health directly, would stimulate economic growth, create jobs, and widen access of the poorest to food (reduction of poverty), thus contributing to maintaining social order[32].

In Brazil today, as was the case in Europe 150 years ago, the great challenge is the reduction of excessive illness among poor adults. Tuberculosis was substituted by CVD as the main cause of death. The expected growth in the number of cases of early CVD over the next 15-20 years, and in older individuals after that, will have a significant impact on the budgets of the National Unified Health System [SUS] and the Ministry of Social Security and Social Assistance [Previdência Social][28,34-35], and affect the productivity and competitiveness of the country in the globalized market.

Chadwick's example demonstrates that it is not necessary to chose between investing in the prevention of diseases in order to reduce the economic impact of illness[1] or intervening in poverty in order to reduce the rates of disease and early death[2]. The best alternative would be to integrate the two strategies, i.e., prioritize health care policies, which besides resulting in direct gains in terms of health care, would stimulate national economic growth and improvement of social conditions. Moreover, it would advance intersector policies of economic development that value the promotion of health and the reduction of morbimortality by chronic illnesses in the population.

**Potential Conflict of Interest**

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

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**Study Association**

This study is not associated with any graduation program.

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