

Trends and spatial distribution of deaths of children aged 12–60 months in São Paulo, Brazil, 1980–98

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Objective To describe trends in the mortality of children aged 12–60 months and to perform spatial data analysis of its distribution at the inner city district level in São Paulo from 1980 to 1998.

Methods Official mortality data were analysed in relation to the underlying causes of death. The population of children aged 12–60 months, disaggregated by sex and age, was estimated for each year. Educational levels, income, employment status, and other socioeconomic indices were also assessed. Statistical Package for Social Sciences software was used for the statistical processing of time series. The Cochrane–Orcutt procedure of generalized least squares regression analysis was used to estimate the regression parameters with control of first-order autocorrelation. Spatial data analysis employed the discrimination of death rates and socioeconomic indices at the inner city district level. For classifying area-level death rates the method of K-means cluster analysis was used. Spatial correlation between variables was analysed by the simultaneous autoregressive regression method.

Findings There was a steady decline in death rates during the 1980s at an average rate of 3.08% per year, followed by a levelling off. Infectious diseases remained the major cause of mortality, accounting for 43.1% of deaths during the last three years of the study. Injuries accounted for 16.5% of deaths. Mortality rates at the area level clearly demonstrated inequity in the city's health profile: there was an increasing difference between the rich and the underprivileged social strata in this respect.

Conclusion The overall mortality rate among children aged 12–60 months dropped by almost 30% during the study period. Most of the decline happened during the 1980s. Many people still live in a state of deprivation in underserved areas. Time-series and spatial data analysis provided indications of potential value in the planning of social policies promoting well-being, through the identification of factors affecting child survival and the regions with the worst health profiles, to which programmes and resources should be preferentially directed.

Keywords Infant mortality/trends; Cause of death; Urban population; Poverty areas; Socioeconomic factors; Social justice; Space-time clustering; Brazil (*source: MeSH, NLM*).

Mots clés Mortalité nourrisson/orientations; Cause décès; Population urbaine; Zone pauvreté; Justice sociale; Corrélation espace-temps; Brésil (*source: MeSH, INSERM*).

Palabras clave Mortalidad infantil/tendencias; Causa de muerte; Población urbana; Areas de pobreza; Justicia social; Agrupamiento espacio-temporal; Brasil (*fuentes: DeCS, BIREME*).

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Introduction

With nearly 10 million inhabitants, São Paulo is one of the largest metropolises in the developing world. Recent demographic changes have been accompanied by social improvements (1). The average life expectancy at birth increased from 56.7 years in 1980 to 70.0 years in 1997, and the infant mortality rate decreased from 72.2‰ in 1980 to 20.9‰ in 1998 (2). Between 1980 and 1996 the proportion of persons aged 65 years or more increased from 4.0% to 5.9% and that of children aged under 5 years fell from 15.9% to 8.1%. The United Nations Development Programme's human development index increased from 0.740 in 1980 to 0.804 in 1991, when the value was similar to those of countries classified as having high human development (3). However, the improvement of health and social conditions in the city has not been uniform. There are still marked social contrasts, significant segments of the population living in a state of deprivation (4).

Monteiro & Benício (5) studied the declining trend of the infant mortality rate in São Paulo during the 1980s in relation to the improvement of social conditions, especially the increased numbers of households with mains water, the schooling levels of parents, and the expanded reach of health services as reflected in vaccination coverage and hospital attendance. Concurrent with the improving profile of infant mortality in the city, the rise in mortality associated with perinatal events and nutritional deficiencies in the poorest areas reflected increasing social inequalities (6). Studies in other countries have shown that differences in infant mortality between socioeconomic groups continue, irrespective of how social conditions are measured, even in communities where a substantial reduction in infant mortality has been achieved (7–11).

Our objectives were to investigate whether the same pattern could be observed in the mortality rates of children aged 12–60 months in São Paulo between 1980 and 1998 in

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relation to the underlying causes of death; to estimate trends; to perform spatial data analysis of death rates; and to evaluate the association between death rates and socioeconomic indicators in different areas of the city.

Methods

Data on deaths of children aged 12–60 months between 1980 and 1998 were obtained from the Foundation for the State System of Data Analysis, the official agency responsible for gathering and managing vital statistics in the State of São Paulo. The records linked mortality data to residential addresses. The age at which each death occurred was determined from the recorded date of death and the date on the deceased's birth certificate. The death registration service was assumed to be reliable and our calculations were made directly, without correction for possible underregistration.

Victora & Barros (12) estimated that the proportion of unreported infant deaths in the South-East Region of Brazil was 1.7%. However, most of them were thought to have occurred in rural areas rather than in the city of São Paulo.

Demographic information was collected from censuses performed in 1980 and 1991, and from a population count in 1996, in order to obtain denominators for the estimation of death rates. The population of children aged 12–60 months, disaggregated by sex and age (13), was estimated for each year and adjusted to 1 July.

The data on per capita household income are area-level means and are linked to the Brazilian standard for income measurement, i.e. the minimum wage, traditionally below US\$ 100 per month but not constant during the study period. The data on crowding refer to average numbers of dwellers per room at the area level, those on water supply to the proportions of households linked to mains water in each district. The Gini coefficient (14, 15), a measure of the concentration of different variables, mainly income, mortality and health service coverage, was employed to assess the inequality of income distribution at the district level. The data on illiteracy among persons aged over 15 years, the number of years of study, and the proportion of high-school graduates refer to the heads of households in each area. Information on these variables was obtained from the 1991 census.

The State Education Secretariat provided information on the proportions of children enrolled in private schools in each area. These data refer to the basic schooling level during 1992–96. Infant death rates and all-age homicide rates, estimated by the direct method, refer to the yearly averages from 1991 to 1998 per 100 000 inhabitants in each area, as given by the Foundation for the State System of Data Analysis. The same agency provided district-level data on employment status, from which average rates of unemployment during 1992–96 were calculated. The continuous survey of unemployment was designed to be representative of the city as a whole and of each of five predefined clusters of areas. The district-level rates of unemployment are not, therefore, representative, although they provide the best indication available to the health authority on this matter.

Statistical processing of time series was performed using SPSS software. The Cochran–Orcutt procedure of generalized least squares regression analysis was used for estimating the regression parameters with control of first-order autocorrelation (16). This model was selected in order to filter the

strong autocorrelation observed in the series, a peculiarity common to diverse magnitudes of social order. It also allowed evaluation of the increasing, stationary or decreasing trend of death rates. See Annex 1 (available on our web site: <http://www.who.int/bulletin>); for a more detailed description of methods employed.

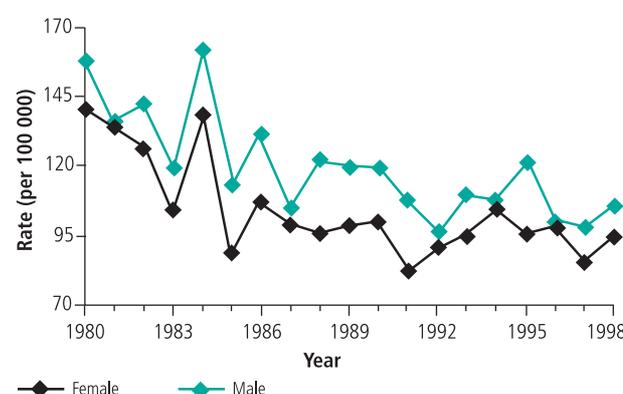
The mortality data for 1991–98 were disaggregated in accordance with the residential areas of the deceased. The geographical unit selected for analysis was the inner-city district. The boundaries of districts comprising homogeneous areas are determined by the Foundation for the Brazilian Institute of Geography and Statistics. These districts form the basis for the targeting of institutional resources and services. The factors guiding this choice were data availability and relevance to local health services. The eight-year period was necessary in order to achieve stable and reliable death figures for each area. We also standardized the mortality rates for children aged 12–60 months at area level by sex and age.

We employed the method of Bailey & Gatrell (17) for the analysis of data discriminated by area. These authors also provided methodological indications for the construction of the proximity matrix in accordance with the criterion of the district neighbourhood. For classifying area-level death rates we used the method of K-means cluster analysis (18). The analysis of spatial correlation between variables was performed by the simultaneous autoregressive regression method, a model taking account of the spatial autocorrelation of rates.

Results

Fig. 1 shows the time series of sex-specific death rates for children aged 12–60 months per 100 000 inhabitants. The ratio of sex-specific death rates remained stationary, and on average there were 15.1% more deaths of males than of females during the period (95% confidence interval (CI): 10.9–19.4%). From 1980 to 1998 there were 16 006 deaths of children in this age range in São Paulo. The mortality rates in 1980, 1984, 1997 and 1998 were 149.0, 150.4, 92.0 and 100.3 per 100 000, respectively. The overall mortality dropped at a mean yearly rate of –3.08% (95% CI: –4.05% to –2.11%) during the 1980s, remaining stationary thereafter.

Fig. 1. Age-standardized sex-specific mortality rates per 100 000 children aged 12–60 months in the city of São Paulo, 1980–98



Sources: Foundation for the State System of Data Analysis; Foundation for the Brazilian Institute of Geography and Statistics.

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In order to investigate the reasons for child deaths we examined the magnitude of and trends in mortality overall and by specific categories of underlying causes. The categories corresponding to the highest rates and those related to preventable causes of death are indicated in Table 1 and Fig. 2. Almost half the recorded deaths were attributable to infectious diseases.

Mortality caused by bronchopneumonia followed the trend of overall deaths. It remained stationary during the 1990s but the overall trend was downwards because of the pronounced decline in the 1980s. Mortality attributable to measles underwent the most marked decrease: it was the second largest cause-specific category of child deaths from 1980 to 1982 and was almost absent after the late 1980s. The highest peaks of measles mortality coincided with peaks in mortality attributable to bronchopneumonia (1980, 1984, 1986), diarrhoea (1980, 1984), sepsis (1984), and nutritional deficiencies (1984, 1986). There was a change in the seasonal pattern of diarrhoea mortality following its decreasing trend. Notwithstanding diarrhoea death rates for summer months had been 50% higher than the average for the remaining months during the 1980s, throughout the 1990s the autumn monthly indices exceeded the average for the remaining

months of the year by 41.2%, possibly reflecting changing etiological factors associated with the environment and sanitation. Injuries were also prominent as specific causes of mortality, and, as with infectious diseases, deaths attributable to injuries presented a decreasing trend overall. However, homicides increased in this age group at a mean annual rate of 2.35% (95% CI: 0.84–3.88%).

Deaths attributable to ill-defined and unspecified causes, including deaths in the absence of medical assistance and those attributed to non-specific signs and symptoms, showed a stationary trend at a low level. For the entire period the proportion of this category of deaths was only 1.76%, indicating that the health services had a good overall ability to elucidate the causes of child mortality.

We performed spatial data analysis of mortality in order to determine whether the indication of decreasing rates was uniform throughout the city. In Fig. 3 (available on our web site: <http://www.who.int/bulletin>) cluster no. 1 includes 12 areas and 8.4% of the population of children aged 12–60 months. Its average risk ratio was approximately half the value for the city as a whole. These areas mostly occupied the central portion of the city, together with the adjacent part of the southern portion, which had the best socioeconomic profile.

Table 1. Mortality of children aged 12–60 months, São Paulo, 1980–98: total deaths, proportions of deaths during different periods, yearly rate of increase in death rates, 95% confidence intervals, and intercluster comparison risk ratios by underlying causes of death.

Underlying cause of death	Total number of deaths	Deaths 1980–82 (%)	Deaths 1996–98 (%)	Yearly rate of increase (%) ^a	95% confidence interval (%) ^a	Intercluster comparison risk ratio ^b
Infectious diseases	7897	58.53	43.13	-2.85	-3.98 to -1.70	1.66
Bronchopneumonia	3757	29.34	19.18	-3.49	-4.84 to -2.13	1.72
Diarrhoea	931	7.95	3.10	-6.54	-8.90 to -4.11	1.96
Measles ^c	618	10.63	0.22	-39.83	-44.30 to -34.99	4.48
Meningococcal meningitis	546	0.46	7.59	+15.50	+11.04 to +20.14	1.59
Bacterial meningitis	463	2.46	3.27	—	Stationary trend	1.33
Sepsis	467	2.46	2.83	-3.03	-4.86 to -1.17	1.94
AIDS ^d	197	—	2.88	+9.44	+1.87 to +17.57	1.24
Tuberculosis	130	1.09	0.55	-6.75	-9.35 to -4.06	1.72
All injuries	2635	13.20	16.46	-1.55	-0.77 to -2.33	1.43
Unintentional injuries	2317	11.56	13.69	-2.08	-3.17 to -0.99	1.59
Traffic-related	923	5.03	5.04	-2.99	-4.35 to -1.61	1.14
Drowning	307	1.69	1.83	-2.47	-4.38 to -0.56	2.05
Fire and burns	243	1.20	1.55	-3.58	-6.79 to -0.26	2.99
Homicides	156	0.57	1.44	+2.35	+0.84 to +3.88	1.87
Congenital anomalies	1097	5.16	9.65	+2.16	+1.41 to +2.91	1.20
Neoplasms	1006	5.14	6.26	-1.22	-1.91 to -0.53	1.22
Non-infectious respiratory diseases	831	4.26	4.93	-1.29	-2.42 to -0.15	2.04
Central nervous system diseases	637	2.54	6.60	+2.32	+0.77 to +3.90	1.21
Nutritional deficiencies ^e	497	3.58	3.44	-12.22	-14.90 to -9.47	2.06
Cardiovascular diseases	484	2.87	2.88	-1.56	-2.69 to -0.42	1.24
Diseases of the digestive system	250	1.04	1.94	—	Stationary trend	2.89
Other causes ^f	390	2.10	2.99	—	Stationary trend	1.44
Ill-defined and unspecified causes	282	1.58	1.72	—	Stationary trend	1.41
All causes	16 006	100.0	100.0	-1.85	-2.45 to -1.25	1.52

Sources: Foundation for the State System of Data Analysis; Foundation for the Brazilian Institute of Geography and Statistics.

^a Rate of yearly increase and confidence interval refer to death rates per 100 000 children in each cause-specific group.

^b Refers to the quotient between cause-specific rates for clusters no. 3 and no. 4, and clusters no. 1 and no. 2.

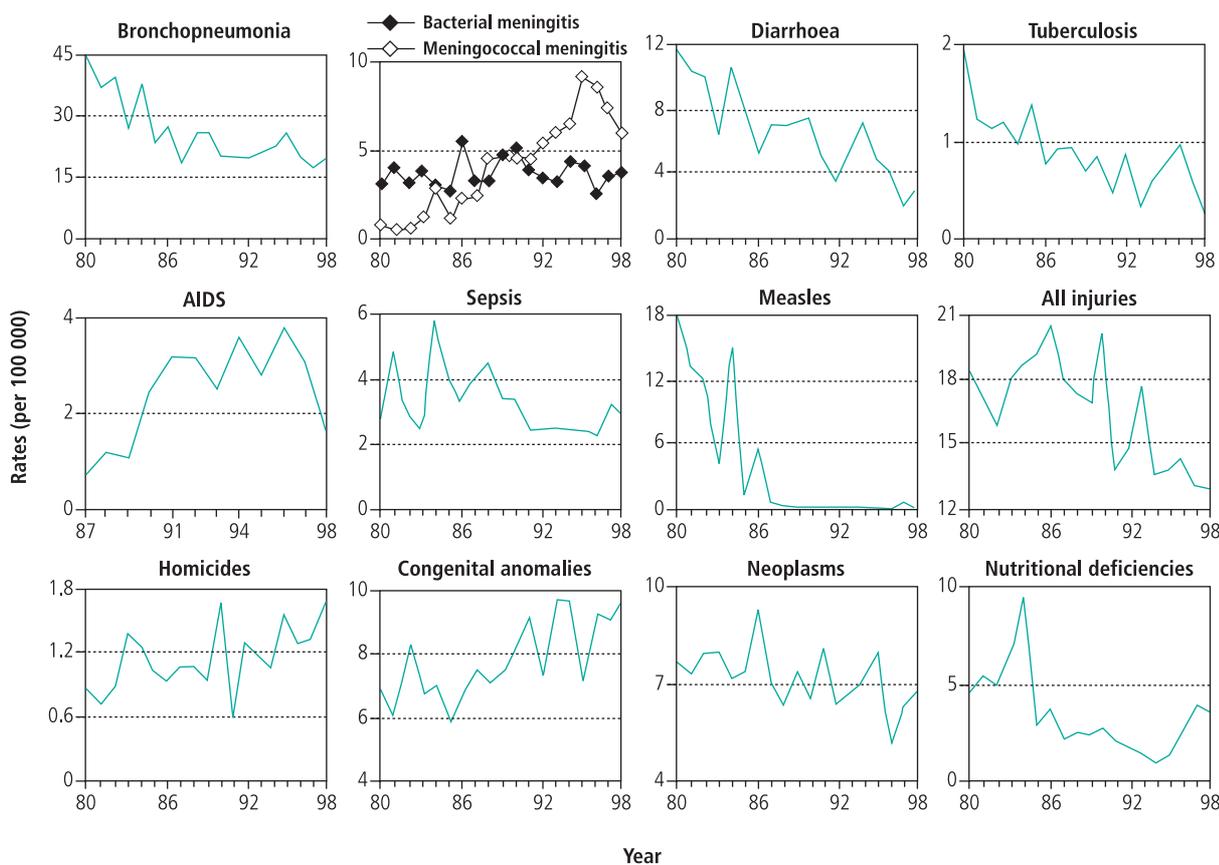
^c Measles increasing trend refers to the period from 1980 to 1991 (Prais-Winsten estimates).

^d All indications of AIDS deaths refer to the period from 1987 to 1998 (Prais-Winsten estimates).

^e Nutritional deficiencies decreasing trend refers to the period 1980–95.

^f Other causes are diseases of the blood and blood-forming organs, endocrine and metabolic diseases, and diseases of the genitourinary system.

Fig. 2. Standardized mortality rates for children aged 12–60 months per 100 000, selected causes, São Paulo, 1980–98



Sources: Foundation for the State System of Data Analysis; Foundation for the Brazilian Institute of Geography and Statistics.

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Cluster no. 2, with an average risk ratio that was approximately 84% of the overall value, occupied a surrounding area of lower socioeconomic status. Cluster no. 3, with an average risk ratio 18.4% higher than the overall value, was located still farther away from the centre. Clusters no. 2 and no. 3, in the most populous parts of the city, contained 51.5% and 35.6% of the children aged 12–60 months respectively. Cluster no. 4, with the highest risk ratio, nearly 3.3 times the average for cluster no. 1 and almost double the overall value, was in districts to the south and north of the centre and in some formerly prosperous central areas where the socioeconomic indicators had declined to a low level. The relatively small number of areas included in this cluster, as well as the low proportion, viz. 4.5%, of the city's children aged 12–60 months living in it, would have to be taken into account when assessing the feasibility of specific policies aimed at improving child survival. Table 1 also shows the intercluster comparison risk ratio, referring to the quotient between average rates for clusters no. 3 and no. 4, containing the areas with increased risk of child death, and clusters no. 1 and no. 2, during 1991–98. The overall figure of 1.52 means that, on average, mortality was 52% higher in clusters no. 3 and no. 4 than in clusters no. 1 and no. 2. The latter also had better social indicators. Subcategories of mortality caused by infectious diseases ranked high on the intercluster comparison risk ratio, pointing to an unequal health profile, with excessive deaths in underprivileged strata. Measles registered the highest intercluster comparison risk ratio, viz. 4.48, indicating that recent measles deaths occurred almost exclusively in poorer

areas of the city. Deaths linked to fire and burns also presented a high intercluster comparison risk ratio, viz. 2.99, indicating a marked disparity between social strata. As 81% of these deaths occurred at home they were possibly associated with fires in slums and shanty towns and with inadequate attendance at nurseries.

Table 2 shows the measurements of correlation between district-level rates and socioeconomic indicators, as obtained by simultaneous autoregressive regression analysis, and summarizes the K-means cluster analysis for the standardized death rates and the descriptive statistics of the demographic characteristics of areas. The mean risk ratios for the clusters further demonstrate the spatial pattern of higher mortality in deprived areas (Fig. 3, available on our web site: <http://www.who.int/bulletin>). Moreover, the display of cluster-level averages for the independent variables helps to scale exploratory associations at the ecological level of factors related to child mortality. In general, districts with higher mortality rates among children aged 12–60 months had higher inequality of income distribution, unemployment, household crowding, illiteracy, all-age homicides and infant death rates, as well as lower incomes, proportions of households with mains water, educational levels, and proportions of children enrolled in private schools. Although social improvements are difficult to achieve in a uniform manner, spatial data analysis allowed us to determine the social conditions most markedly associated with poorer child survival.

Table 2. K-means cluster analysis for mortality rates of children aged 12–60 months, population characteristics of areas and simultaneous autoregressive (autocorrelated errors model) correlation coefficient between variables, São Paulo, 1980–98

Mortality rate for children aged 12–60 months	Cluster no. 1	Cluster no. 2	Cluster no. 3	Cluster no. 4		
Mean risk ratio, in comparison to city as a whole	0.551	0.843	1.184	1.819		
Standard deviation	0.085	0.086	0.094	0.121		
Number of areas	12	27	13	6		
Children aged 12–60 months inhabiting cluster in 1991	60 410	372 585	256 915	32 665		
Overall population (1991)	1069 321	5139 855	3026 414	410 595		
% of children aged 12–60 months	5.6	7.2	8.4	8.0		
Population characteristics					Coefficient	Significance
Household income	10.06	6.29	5.67	5.66	-0.448	$P < 0.001$
Gini coefficient	0.47	0.56	0.53	0.54	+0.347	$P = 0.004$
Unemployment rate (%)	10.10	12.39	13.02	12.75	+0.239	$P = 0.036$
Household crowding	0.50	0.67	0.76	0.73	+0.389	$P = 0.001$
Water supply (%)	94.26	93.76	93.55	84.71	-0.333	$P = 0.005$
Illiteracy rate (%)	3.12	4.76	5.35	5.43	+0.402	$P < 0.001$
Years of study	10.44	7.82	7.35	7.45	-0.389	$P < 0.001$
Graduated from high school (%)	54.82	31.25	27.21	28.87	-0.376	$P = 0.002$
Children enrolled in private schools (%)	46.32	25.48	14.91	31.49	-0.390	$P < 0.001$
All-age homicide rate (per 100 000 inhabitants)	16.29	33.46	48.68	55.36	+0.574	$P < 0.001$
Infant death rate (‰)	17.89	21.79	30.25	33.62	+0.782	$P < 0.001$

Sources: Foundation for the State System of Data Analysis; Foundation for the Brazilian Institute of Geography and Statistics.

Fig. 4 (available on our web site: <http://www.who.int/bulletin>) presents yearly values of the ratios between death rates in each cluster and the overall rate. As the ratio denominator was the mortality rate among children aged 12–60 months in the city as a whole, the basis for comparison of time series for each cluster was the horizontal line at level 1 on the ordinal axis. From 1991 to 1998 the time series associated with clusters no. 1, no. 2 and no. 3 remained stationary. However, the time series for cluster no. 4, indicating changes in the ratio between the mortality rate for children aged 12–60 months in cluster no. 4, which had the worst mortality profile, and that for the city as a whole, increased at a yearly rate of 5.73% (95% CI: 3.95–7.55%). This indicated that excess child mortality in deprived areas increased in recent years.

Discussion

The overall mortality rate among children aged 12–60 months dropped by almost 30% during the study period. The decline in some cause-specific death rates was even higher: nearly 50% for deaths attributed to bronchopneumonia and more than 70% for those caused by diarrhoea and tuberculosis. Studies on morbidity and mortality in São Paulo have linked the improving profile of indicators with social characteristics, such as the increased coverage of health services, the provision of mains water in almost all parts of the city, higher educational levels of parents, reduced fertility, and measles control (19–23).

In comparison with child mortality data for São Paulo covering the period 1968–72 (24), the more recent data show a marked improvement. However, most of the reported decline in child mortality happened during the 1980s and many people still live in a state of deprivation in underserved areas (4). During the 1990s, increasing unemployment and economic adversity may have helped to maintain overall mortality among children aged 12–60 months stationary at a high level.

Furthermore, although the reform of the health system after 1990 increased access to medical services, the delivery of care continued to be inequitable throughout whole country. Almeida et al. (25) reported that utilization rates varied between income groups, positions in the labour market and levels of education. They also found that underfunding, fiscal stress and a lack of priorities for the health sector, together with regressive tax collection and an unequal distribution of financial resources among regions had contributed to a steady deterioration of services.

There was an increasing trend in the number of deaths attributable to meningococcal meningitis and AIDS during the study period, in contrast to what was observed in relation to most infectious diseases. An epidemic of group B *Neisseria meningitidis* meningococcal meningitis began in the mid-1980s (26), when no vaccine with protective efficacy was available (27). Mortality attributable to AIDS among children aged 12–60 months began to decrease after 1996, possibly as a consequence of new medical technology and knowledge on the vertical transmission of HIV (28).

Although deaths attributable to nutritional deficiencies fell consistently until the mid-1990s, there was a subsequent rise in the time series. Studies on food intake and the anthropometrics of preschool children indicated improvements in nutritional status that were attributed to moderate increases in family incomes (29–31). The intercluster comparison risk ratio of 2.06 for deaths caused by nutritional deficiencies, with higher levels of mortality in the underprivileged social strata, confirmed the differential distribution of such deficiencies. However, the epidemiological synergism between malnutrition and other causes of death, especially respiratory infections and diarrhoea, should be taken into account (32). Murray & Lopez (33) considered that nutritional deficiencies were in some measure responsible for 55% of child deaths in developing countries during 1995.

The mortality rate attributable to congenital anomalies among children aged 12–60 months also increased. Furthermore, this was an important category of cause-specific infant mortality, accounting for 12.9% of infant deaths during 1991–98; this corresponded to an average cause-specific yearly death rate of 3.47‰ (95% CI: 3.30–3.65‰, stationary trend). Since the ratio of death rates attributable to congenital abnormalities between children aged 12–60 months and infants was 10.2% during the 1990s, the increasing trend observed in the former group possibly reflected improvements in medical care and the extended survival of some children who, otherwise, would have died at an earlier age. Moreover, the intercluster comparison risk ratio of 1.20 meant that areas with the worst social profile presented a lower excess of birth-defect deaths than the overall intercluster excess of deaths. This suggested the need to conduct further studies associating deaths attributable to birth defects with the age of the deceased.

In the USA there were decreases in death rates of children aged 12–60 months from 63.9 per 100 000 in 1980 to 35.8 per 100 000 in 1997 and to 34.4 per 100 000 in 1998 (34). These values were appreciably lower than those in São Paulo. Furthermore, the leading causes of mortality in the USA during the latter period (1997–98) were unintentional injuries, birth defects, neoplasms, homicides, heart disease and pneumonia in that order, whereas infectious diseases comprised the major category of causes throughout the study period in São Paulo. Data supplied by the WHO Statistical Information System (<http://www.who.int/whosis/>) show that, in 1996, Argentina and Cuba had lower mortality rates among children aged 12–60 months than São Paulo, viz. 81.4 and 62.6 per 100 000, respectively. However, in the richer half of Brazil, i.e. the South, South-East and Mid-West Regions, the corresponding value in 1995 was 106.9 per 100 000, indicating an even worse profile at the country level than in São Paulo.

UNICEF (35) considers the mortality rate among children aged under 5 years to be a critical indicator of well-being and classifies Brazil as having the 85th-highest figure globally. A WHO index of child survival placed Brazil in 108th position, below several countries with lower gross national products per capita (36). In a study encompassing nine developing countries it was found that, as between different socioeconomic strata, Brazil had the most unequal distribution of mortality among children aged under 5 years (37). While the under-5 mortality rate is largely indicative of patterns related to infants, its study has nevertheless yielded information relevant to the present discussion on inequities and trends in mortality among children aged 12–60 months in São Paulo.

Although São Paulo had lower death rates than those reported nationally, the study of intraurban geographical patterns of indicators revealed remarkable inequalities by showing that child mortality was comparatively high in deprived areas. This was consistent with evidence from Australia (38) and pointed to the complex nature of the relationship between socioeconomic status and health (39).

Deprivation per se can increase the risk of several diseases, and underprivileged social strata present a profile of heightened adverse risk factors. Families subjected to poor living and working conditions are less exposed than others to information on health and are more likely to engage in health-damaging behaviours. The underprivileged make less use of the health care system for preventive purposes; their nutritional status is comparatively poor; and they have inferior access to early diagnosis, fewer therapeutic resources, and worse prognoses when diseases develop. Furthermore, Victora et al. (40) reported that the introduction of new medical technologies in Brazil initially mostly benefited the higher socioeconomic strata. If health initiatives take place before the removal of social gaps and inequities they can thus worsen the relative position of the underprivileged in respect of disease incidence.

The present study revealed indicative elements of an overall decreasing trend in mortality among children aged 12–60 months in São Paulo, concurrent with an increasing gap between rich and deprived areas of the city in this matter. The need to target resources and programmes at the groups in greatest need was clearly demonstrated. By revealing factors associated with an increased risk of death, time-series and spatial data analyses suggested how to promote well-being and the planning of services.

The temporal and spatial assessment of epidemiological data can lead to improvements in the effectiveness of social policies by guiding the targeting of resources and identifying groups to which educational measures and health programmes should be preferentially directed. ■

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Conflicts of interest: none declared.

Résumé

Tendances et distribution spatiale des décès chez l'enfant de 12 à 60 mois à São Paulo (Brésil), 1980-1998

Objectif Décrire les tendances de la mortalité chez l'enfant de 12 à 60 mois et réaliser une analyse de la distribution des données spatiales au niveau des districts du centre de la ville de São Paulo de 1980 à 1998.

Méthodes Les données officielles de mortalité ont été analysées par rapport aux causes de décès. La population des enfants de 12 à 60 mois, répartie par sexe et par âge, a été estimée pour chacune des années. Le niveau d'instruction, le revenu, la situation professionnelle et divers autres indicateurs socio-économiques ont

également été évalués. Le traitement statistique des données des séries chronologiques a utilisé le logiciel « *Statistical Package for Social Sciences* ». La régression généralisée par la méthode des moindres carrés décrite par Cochrane-Orcutt a permis d'estimer les paramètres du modèle rendant compte de l'autocorrélation de premier ordre. L'analyse des données spatiales a utilisé la discrimination des taux de décès et des indicateurs socio-économiques au niveau des districts du centre de la ville. La classification des taux de décès par secteur géographique a utilisé

l'algorithme des centres de groupe dit méthode des « *K-means* ». La corrélation spatiale entre les variables a été analysée par la méthode autorégressive simultanée.

Résultats Au cours des années 1980, on observe un déclin constant du taux de décès à la vitesse moyenne de 3,08 % par an, suivi d'une stabilisation. Les maladies infectieuses restent la cause principale de mortalité, représentant 43,1 % des décès au cours des trois dernières années de l'étude. Les traumatismes représentent 16,5 % des décès. Les taux de mortalité par secteur géographique mettent nettement en évidence l'iniquité de la situation sanitaire au sein de la ville : on observe en effet un accroissement de l'écart entre les couches sociales riches et défavorisées.

Conclusion Le taux de mortalité global des enfants de 12 à 60 mois a chuté de près de 30 % pendant la période d'étude. Le déclin se situe pour l'essentiel pendant les années 80. Un grand nombre de personnes vivent encore dans le dénuement et dans des zones mal desservies. L'analyse des séries chronologiques et des données spatiales fournit des indications sur l'intérêt potentiel de la planification des politiques sociales pour la promotion du bien-être ; à cette fin, on identifiera les facteurs qui interviennent dans la survie de l'enfant et les régions où le profil sanitaire est le plus défavorable, vers lesquelles seront dirigés préférentiellement les ressources et les programmes.

Resumen

Tendencias y distribución espacial de las defunciones de niños de 12 a 60 meses de edad en São Paulo (Brasil), 1980-1998

Objetivo Describir las tendencias de la mortalidad de los niños de 12 a 60 meses de edad, y realizar análisis espaciales de su distribución entre los distritos del casco urbano de São Paulo entre 1980 y 1998.

Métodos Se analizaron los datos oficiales de mortalidad considerando los casos subyacentes de defunción. Para cada año se estimó la población infantil de 12 a 60 meses de edad, desagregada por sexo y edades. Se evaluaron asimismo el nivel educativo, los ingresos, la situación laboral y otros índices socioeconómicos. Las series temporales se procesaron estadísticamente mediante el paquete SPSS (Statistical Package for Social Sciences). Para estimar los parámetros de regresión, con control de la autocorrelación de primer orden, se empleó el método Cochran-Orcutt de análisis de regresión de mínimos cuadrados generalizado. El análisis de los datos espaciales se basó en la discriminación de las tasas de defunción y los índices socioeconómicos entre los distritos del casco urbano. Para clasificar las tasas de defunción por áreas se empleó el método de análisis por conglomerados basado en las *k*-medias. La correlación espacial entre variables se analizó mediante el método de regresión autorregresiva simultánea.

Resultados Se observó una disminución constante de las tasas de defunción durante los años ochenta, a razón de 3,08% al año como media, seguida de una estabilización. Las enfermedades infecciosas fueron en todo momento la principal causa de mortalidad y representaron el 43,1% de las defunciones durante los últimos tres años del estudio. Los traumatismos causaron el 16,5% de las muertes. Las tasas de mortalidad por áreas demostraron claramente la desigual distribución de la salud en la ciudad: una diferencia creciente separa a los ricos de los estratos sociales desfavorecidos.

Conclusión La tasa global de mortalidad de los niños de 12 a 60 meses cayó casi un 30% durante el periodo de estudio. La mayor parte de esa disminución se produjo en los años ochenta. Muchas personas siguen viviendo en un estado de privación en zonas subatendidas. El análisis de las series temporales y de los datos espaciales aportó indicaciones potencialmente útiles para planificar políticas sociales favorables al bienestar, pues permitió identificar factores que afectan a la supervivencia infantil y a las regiones con peor situación sanitaria. A ellos deberán orientarse preferentemente los programas y los recursos.

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Annex 1

Heteroscedasticity, non-normal distribution and autocorrelation are usual characteristics of social measures datasets which prevent regression analysis. A prior control of these characteristics is required both for trend estimation and for performing spatial data analysis.

The Kendall-Stuart and Goldfeld-Quandt tests (41) allow the dimensioning of heteroscedasticity in variables and in the distribution of regression residuals, both for time-series and spatial data analysis. The Kolmogorov-Smirnov goodness-of-fit test (13) evaluates whether the distribution of variables can be considered normal. The Durbin-Watson indicator (42) tests the autocorrelation of time-series, and Moran's I coefficient (17) guides the detection of spatial autocorrelation of variables. The power transformations of Box & Cox (18) permit the correction of heteroscedasticity and non-normality of the distribution of variables.

In order to perform trend estimation for a given data-set, begin with $\log Y = a + bX$, where Y is the dependent variable (the rate itself or the Box-Cox-transformed rate) and X is the year. Estimate b by using the Cochrane-Orcutt procedure of generalized least squares regression analysis. Prefer Prais-Winsten estimates only for short time intervals, because this method involves one further step of estimation, which allows maintenance of the original number of degrees of freedom. Avoid ordinary least squares regression analysis, which does not account for temporal autocorrelation and tends to produce misleading regress parameters and to overestimate goodness-of-fit indicators.

For any year i included in the study period,

$$\log Y(i) = a + bi,$$

$$\text{and } \log Y(i+1) = a + b(i+1).$$

Then, by differencing

$$\log Y(i+1) - \log Y(i) = b(i+1-i) = b, \text{ which can be written as:}$$

$$Y(i+1)/Y(i) = 10^b; \text{ or}$$

$$[Y(i+1) - Y(i)]/Y(i) = -1 + 10^b; \text{ or}$$

$$yri = -1 + 10^b;$$

where yri refers to the yearly rate of increase of the measure Y. If the original values have been transformed algebraically it is necessary to undo the transformation before obtaining the real yearly rate of increase. A negative value of yri indicates a decreasing trend, while a value non-significantly different from

zero indicates a stationary trend. By using the standard error provided by regression analysis for the coefficient b, the observed number of degrees of freedom, and the t-test table, the 95% confidence interval for the b coefficient and the yearly rate of increase can be estimated. An introduction to time-series analysis is given by Gaynor & Kirkpatrick (42).

Geographical patterns of area-level rates can be studied by estimating their association with social indicators. Ordinary least squares regression analysis is not suitable for spatially correlated measures. The simultaneous autoregressive procedure of generalized least squares regression analysis should therefore be applied (17). Although several more complex forms of the simultaneous autoregressive procedure are possible, this model can be applied by performing the following steps.

$$\text{Assume that } (I - \rho W)Y = (I - \rho W)X\beta + \varepsilon;$$

where I is the identity matrix;

W is the standardized proximity matrix;

ρ is the interaction parameter, which accounts for spatial autocorrelation;

β is the regression coefficient;

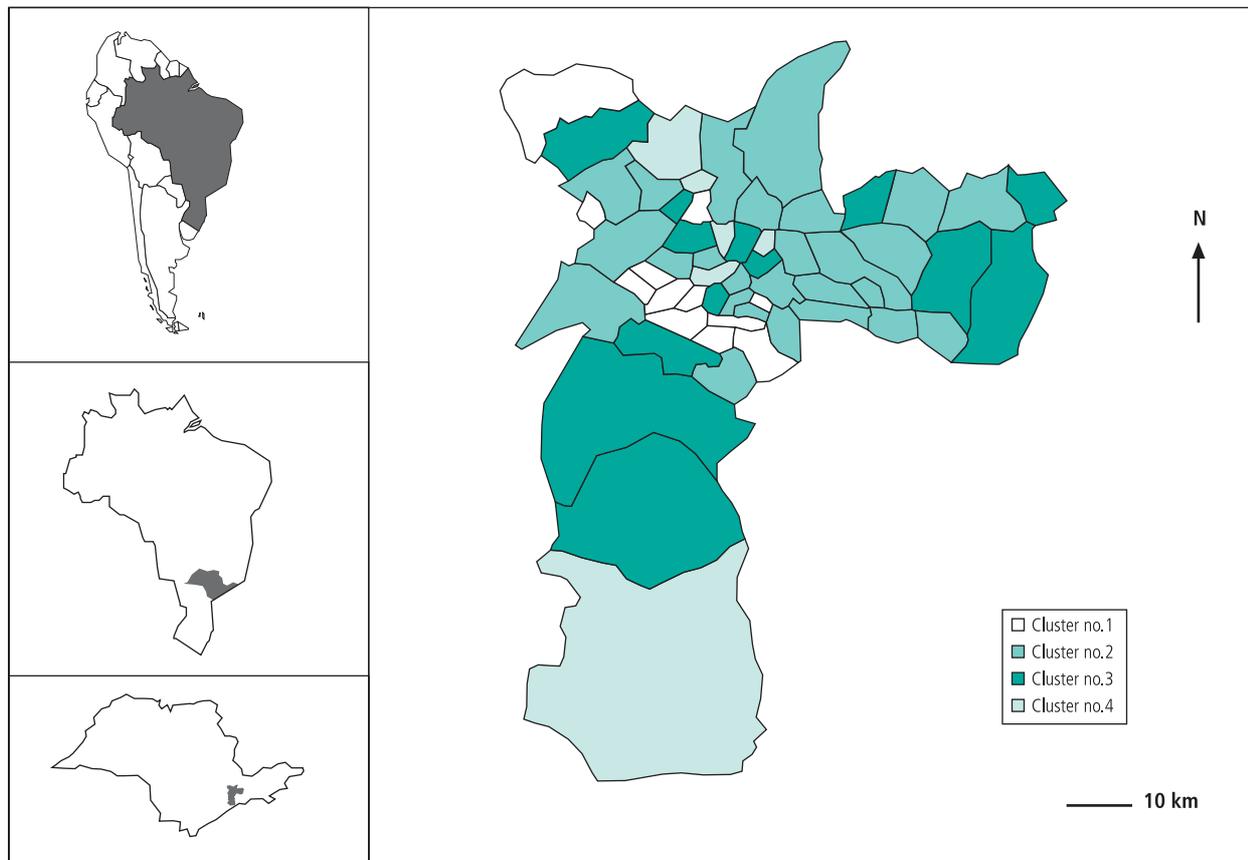
ε is the error-term vector;

Y and X are the vectors of values whose association is to be estimated.

Multivariate analysis can be assessed by an analogous procedure.

Regression analysis between Y and X poses the difficulty of simultaneously estimating the β -regression coefficient and ρ , which requires computationally intensive maximum likelihood estimation. This problem can be solved by using a multistep iterative scheme. Ordinary least squares regression analysis is run between $(I - \rho W)Y$ and $(I - \rho W)X$, assuming any value for ρ , since $0 < \rho \leq 1$. ε (the vector of errors for each area) should then be obtained. Ordinary least squares regression analysis is again run by regressing ε and $\rho W\varepsilon$. The former estimation of ρ is refined in order to achieve the $0 < \rho \leq 1$ condition, where b is the regression coefficient of the equation involving the error term. To further refine the estimation of ρ , its estimated value has to be approached to the resulting value of b. This procedure then has to be iterated until convergence between ρ and the b coefficient of the error-term regression analysis is achieved.

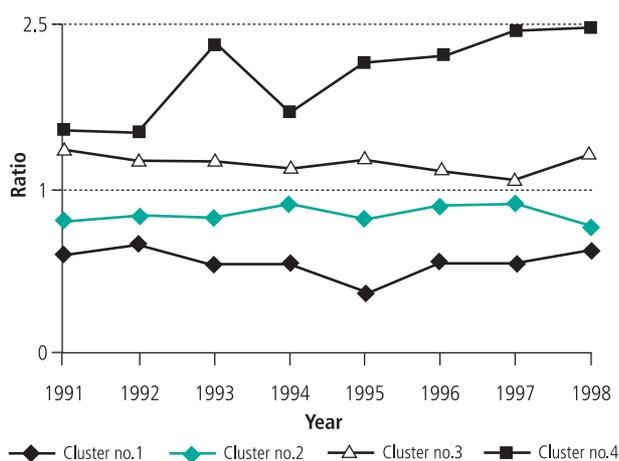
Fig. 3. K-means clustering analysis of standardized mortality rates for children aged 12–60 months in São Paulo areas, 1991–98



Sources: Foundation for the State System of Data Analysis; Foundation for the Brazilian Institute of Geography and Statistics.

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Fig. 4. Ratios between death rates for children aged 12–60 months in each cluster and in the city as a whole, São Paulo, 1991–98



Sources: Foundation for the State System of Data Analysis; Foundation for the Brazilian Institute of Geography and Statistics.

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