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Intraurban Variations in Adult Mortality in a Large Latin American City

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ABSTRACT *Urbanization is high and growing in low- and middle-income countries, but intraurban variations in adult health have been infrequently examined. We used spatial analysis methods to investigate spatial variation in total, cardiovascular disease, respiratory disease, and neoplasm adult mortality in Buenos Aires, Argentina, a large city within a middle-income country in Latin America. Conditional autoregressive models were used to examine the contribution of socioeconomic inequalities to the spatial patterning observed. Spatial autocorrelation was present in both men and women for total deaths, cardiovascular deaths, and other causes of death (Moran's Is ranging from 0.15 to 0.37). There was some spatial autocorrelation for respiratory deaths, which was stronger in men than in women. Neoplasm deaths were not spatially patterned. Socioeconomic disadvantage explained some of this spatial patterning and was strongly associated with death from all causes except respiratory deaths in women and neoplasms in men and women [relative rates (RR) for 90th vs 10th percentile of percent of adults with incomplete high school and 95% confidence intervals: 1.23 and 1.09–1.39 vs 1.24 and 1.08–1.42 for total deaths in men and women, respectively; 1.36 and 1.15–1.60 vs 1.22 and 1.01–1.47 for cardiovascular deaths; 1.21 and 0.97–1.52 vs 1.07 and 0.85–1.34 for respiratory deaths; 0.94 and 0.85–1.04 vs 1.03 and 0.87–1.22 for neoplasms; and 1.49 and 1.20–1.85 vs 1.63 and 1.31–2.03 for other deaths].There is substantial intraurban variation in risk of death within cities. This spatial variability was present for multiple causes of death and is partly explained by the spatial patterning of socioeconomic disadvantage. Our results highlight the pervasive role of space and social inequalities in shaping life and death within large cities.*

KEYWORDS *Adult mortality, Latin America, Social factors, Spatial patterning, Urbanization.*

INTRODUCTION

Nearly 50% of the world population lives in urban areas. This number is expected to reach 60% by the year 2030.[1] More than two thirds of the world's urban population lives in Africa, Asia, or Latin America.[2] Levels of urbanization are especially pronounced in Latin America, where nearly 80% of the population lives in urban areas.[3] In some countries, such as Argentina, the urban population approaches 90% of the total population.[4] Latin America is also home to some of

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the world's largest metropolitan areas, including the city of Buenos Aires in Argentina.

Much work has focused on identifying the health impacts of urbanization. For example, a recent cross-national study found that the percent of the country population that is urban is positively associated with body mass index and cholesterol.[5] It has been suggested that features of urban life, such as increased intake of processed foods, reliance on private motorized transportation, and aspects of the organization of work may result in unhealthy diets and decreased physical activity.[6,7] Environmental exposures such as air pollution associated with city life have been linked to cardiovascular and respiratory disease.[8] Physical and psychosocial work characteristics more common in cities may place city dwellers at higher risk for cardiovascular diseases and cancer.

An important feature of urban areas is the presence of large heterogeneity in socioeconomic circumstances and resources. The acceleration in the rate of urbanization has been accompanied by increases in urban poverty. It has been estimated that 43% of the urban population in developing countries lives in slums.[1] However, many cities retain a core of wealthy areas, and others have experienced varying degrees of gentrification of previously marginalized areas. This results in enormous inequality in environmental conditions within cities. Clearly, the consequences of urbanization are not the same for all.

Heterogeneity in health within urban areas has rarely been examined, especially in middle-income countries where the levels of urbanization are particularly striking. Although some reports have focused on intraurban variations in violent deaths, infectious diseases, or child health,[9–11] within-city variations in deaths due to the most common diseases of adulthood (cardiovascular disease, respiratory disease, and cancer) have been infrequently investigated. Using spatial analysis methods, we investigated spatial variation in total, cardiovascular disease, respiratory disease, and cancer adult mortality and the associations of these variations with socioeconomic inequality in the city of Buenos Aires, Argentina (a city of nearly three million people) in 2003.

METHODS

All analyses were restricted to adults 20 years of age and older. Data on deaths occurring in the city of Buenos Aires during the year 2003 were obtained from vital statistics registries. Causes of death were coded into ICD-10 codes by trained coders. Cause of death was determined by the underlying cause of death and classified as follows: cardiovascular (ICD10 codes I00–I99), respiratory (ICD10 codes J00–J99), and neoplasms (ICD10 codes C00–D48). These are the three most common causes of death in adults aged 20 years and older in the city, accounting for 30.9, 22.6, and 22.0% of all deaths, respectively. All other deaths were classified into an "other" category.

Denominators for the calculation of mortality rates were obtained from the year 2001 national census because interpolated estimates for subsequent years were not available. Mortality rates were estimated for each censal fraction in the city. Censal fractions were designed by the Argentine National Institute of Statistics and Censuses based on criteria related to the logistic of the censuses. Of the 286 censal fractions in the city, two were combined due to changes over time in boundaries and four outliers with very low population counts (less than 2,000 adults aged 20 years and older) were excluded, leaving a total of 281 available for analysis. Each death was assigned to a censal fraction using usual place of residence address information recorded on the death certificates. Of the total of 34,259 deaths registered in the city during 2003, 1,062 were excluded because they corresponded to non-city residents. Of the remaining 33,197, a total of 94% (31,329) were geocoded to the level of censal fraction. Of these, 30,789 were deaths occurring in adults 20 years of age or over residing in censal fractions included in the analyses. Geocoded and non-geocoded deaths did not differ significantly in age, sex, cause of death, month of death, or health care services at time of death. They also did not differ significantly in health insurance coverage or education (although very limited information was available on these two variables).

To examine the contribution of socioeconomic characteristics to spatial variations in mortality rates, socioeconomic data were obtained from each censal fraction from the year 2001 census. The percentage of adults 25 years of age or over without high school diplomas was used as the main socioeconomic indicator in the analyses. This indicator was selected because it is commonly available and was correlated with other available indicators including inadequate housing and percent of population with unmet basic needs. It was used as a marker of the general socioeconomic circumstances of the area rather than as a marker of education per se. Hence, all results refer to socioeconomic patterning generally, rather to patterning by education.

Mortality rates were adjusted for age using the direct method and the age distribution of the full city as the standard. Moran's I,[12] a global index of spatial autocorrelation, was used to quantify the amount of spatial patterning in the age-adjusted rates. The value of Moran's I will be positive when neighboring regions tend to have similar values, and negative when neighboring regions tend to have different values. The queen's weight matrix was used for all estimates of Moran's I. The queen's weight matrix gives equal weight to censal fractions that have common border and/or vertices with the index censal fraction. Although *P* values for Moran's I can be obtained from software packages, they are not reported here because they are based on often incorrect normality and randomization assumptions.[13] Instead, we report pseudo *P* values estimated by Geoda software based on a random permutation approach.[14] Similar results were obtained when Moran's I was estimated using empirical Bayes standardization of rates (to account for differences in population size by censal fraction. Results not shown).[15]

Moran's I provides information on the presence of spatial autocorrelation averaged over the whole study area but does not provide information on the presence of individual clusters within the area. Local Moran's I, a type of local indicator of spatial autocorrelation (LISA), was used for this purpose.[16] This indicator provides a local measure of the similarity between each area's value and those of nearby areas. These values and their statistical significance can be mapped to provide insight into the location of areas with comparatively high or low local associations with neighboring values.[13] This method is used to detect clusters of high and low values.

After examination of spatial autocorrelation in rates, we used spatial empirical Bayes smoothing[17–19] to map spatially smoothed age-adjusted rates. The queen's weight matrix was used for spatial weights in the smoothing. Other weighting schemes yielded similar patterns. This method is appropriate when spatial patterning is present in the rates and when rates are based on heterogeneous denominators. Using this method, rates from areas with low population are shrunk towards a local mean, defined based on the spatial weight matrix used.

Associations of area socioeconomic characteristics with mortality rates were estimated using Poisson regression to model the log number of deaths in each tract as a function of the percent of the population in five age categories (20–44, 45–64, 65–74, 75–79, and 80+), the socioeconomic indicator, and an offset for the population size. The spatial patterning of these rates was accounted for by using intrinsic conditional autoregression models, which account for the spatial dependency of the rates.[20] The queen's weight matrix was used in these analyses. Models were fitted using the GLIMMIX macro in SAS.[20]

Assuming that O_i is the observed deaths in censal fraction i and P_i is the population of adults 20 and over in censal fraction i, and $O_i \sim \text{Poisson}(\mu_i)$, the model fitted is:

$$\log(\mu_i) = \alpha_0 + \alpha_1 \text{PISI}_i + b_i + \log(P_i)$$

where PISI_i = percent of population without a high school diploma, b_i = random component for each censal fraction (random effect), and $\log(P_i)$ = logarithm of the population of censal fraction i (offset term), and the conditional distribution of the random effects b_i is:

$$b_i \middle| b_j \sim N\left(\overline{b}_{i_j}, \frac{\sigma_{\text{spat}}^{\;2}}{n_j}\right)$$

where $\overline{b}_i = \sum_{j \in \partial_i} b_j / n_i$, n_i is the number of neighbors for area i and δ_i indicates the neighborhood of area i, σ_{spat} is the spatial covariance, and N indicates normally distributed.

We estimated the contribution of area socioeconomic characteristics to the spatial patterning of the rates by estimating spatial autocorrelation in residuals from standard Poisson models (with no spatial autocorrelation term) before and after adding the socioeconomic indicator. The output from GLIMMIX cannot formally be used to evaluate the different models, and P values for the variance components can be suspect due to the way the test statistic is distributed.[21] However, P values for the spatial component are sometimes used as a rough indication of the importance of the spatial component. Analyses were conducted using arcGIS (ESRI, Redlands, CA, USA), Geoda (Anselin L. GeoDa Software. 0.9.5-i ed. Urbana: The Regents of the University of Illinois; 2004), SAS (SAS Institute, Cary, NC, USA), and R (The R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Selected characteristics of deaths included in the analyses are shown in Table 1. Total crude annual mortality rates for the city were 15.1 per 1,000 in men and 14.0 per 1,000 in women. Over three-quarters of all deaths (75.6% in men and 87.1% in women) occurred in persons 65 years of age and older. Age-adjusted mortality rates were higher in men than in women (Table 1). Table 2 shows selected characteristics of censal fractions in the city. Censal fractions have a median population of approximately 3,600 persons and a median size of 0.5 km^2. The median total number of deaths in persons 20 years old and older per censal fraction was 49 in men and 57 in women. The median percent of persons without high school degrees was 38.8%. There was substantial variation in socioeconomic characteristics across censal fractions within the city.

There was substantial variation in death rates across censal fractions (Table 3). Spatial autocorrelation was present in both men and women for total deaths,

TABLE 1 Selected characteristics of deaths among persons 20 years of age and over occurring in the city of Buenos Aires during 2003

	Men	Women
Number	14,081	16,708
Crude death rate per 1,000	15.1	14.0
Percent distribution of deaths by age		
20–44	5.3%	2.5%
45–64	19.1%	10.3%
65–74	23.3%	13.6%
75–79	17.0%	13.5%
80+	35.3%	60.0%
Percent distribution of deaths by major causes of death[a]		
CVD	29.8%	31.8%
Cancer	23.8%	20.5%
Respiratory	21.6%	23.4%
Other	24.8%	24.3%
Age-adjusted annual death rate (per 1,000)		
All causes	19.1	11.8
CVD	5.7	3.7
Respiratory	4.3	2.6
Neoplasms	4.3	2.7
Other	4.7	2.9

CVD = cardiovascular disease

[a]Geocoded and nongeocoded deaths had very similar distributions by age and cause of death. Cardiovascular deaths include ICD10 codes I00–I99, respiratory deaths include ICD10 codes J00–J99, and neoplasms deaths include ICD10 codes C00–D48. Within “other” deaths, the four most common causes are genitourinary system N00–N99 (19.6%), external causes (intentional and unintentional injuries) V01–Y98 (14.3%), not elsewhere classified R00–R99 (14.1%), and infectious diseases A00–B99 (13.5%) in men; and genitourinary system (19.2%), not elsewhere classified (15.2%), infectious diseases (11.7%), and mental and behavioral disorders F00–F99 (mostly unspecified dementia) (7.6%) in women

cardiovascular deaths, and other causes. The spatial patterning was generally stronger in men than in women and was strongest for total deaths. There was some spatial autocorrelation for respiratory deaths, with the correlation being stronger in men than in women. Neoplasm deaths were not spatially patterned. Moran’s I values were very similar when empirical Bayes rate standardization[15] was used to account for the variance instability of rates due to varying denominator sizes (not shown).

Figure 1 shows spatially smoothed death rates in men and in women for the causes of death for which spatial patterning was apparent. Maps for all cause,

TABLE 2 Selected characteristics of censal fractions in the city of Buenos Aires, 2003

	Median (10th–90th percentile)
Total population ≥20 years of age	3,595 (2,436–5,275)
Area (km^2)	0.51 (0.20–1.29)
Total number of deaths ≥20 years of age (men/women)	49 (30–73)/57 (36–85)
Cardiovascular disease deaths	14 (7–23)/18 (10–29)
Respiratory deaths	10 (5–18)/13 (6–22)
Neoplasm deaths	11 (6–19)/12 (6–18)
Other deaths	212 (6–20)/14 (7–22)
Percent of population without a high school diploma	38.8 (20.2–55.6)

TABLE 3 Distribution of censal fraction age-adjusted annual death rates (per 1,000) in men and women, Buenos Aires, Argentina, 2003

	5th percentile	25th percentile	50th percentile	75th percentile	95th percentile	Moran's I[a]	Pseudo *P* value
Male							
Total	9.97	12.88	14.81	17.06	20.87	0.37	0.001
CVD	2.39	3.43	4.36	5.44	7.05	0.25	0.001
Respiratory	1.45	2.45	3.17	4.01	5.50	0.20	0.001
Neoplasms	2.08	2.84	3.55	4.35	5.50	0.00	0.430
Other	1.64	2.78	3.61	4.50	6.40	0.18	0.001
Female							
Total	10.11	12.03	13.67	15.76	18.94	0.24	0.001
CVD	2.58	3.48	4.38	5.24	6.90	0.13	0.001
Respiratory	1.64	2.46	3.23	3.97	5.31	0.08	0.009
Neoplasms	1.49	2.29	2.91	3.43	4.53	0.03	0.160
Other	1.62	2.55	3.33	4.10	5.54	0.15	0.001

CVD = cardiovascular disease

[a]Negative values indicate clustering of dissimilar values or negative spatial autocorrelation, 0 indicates a random scatter or no spatial autocorrelation, and positive values indicate clustering of similar values or positive spatial autocorrelation

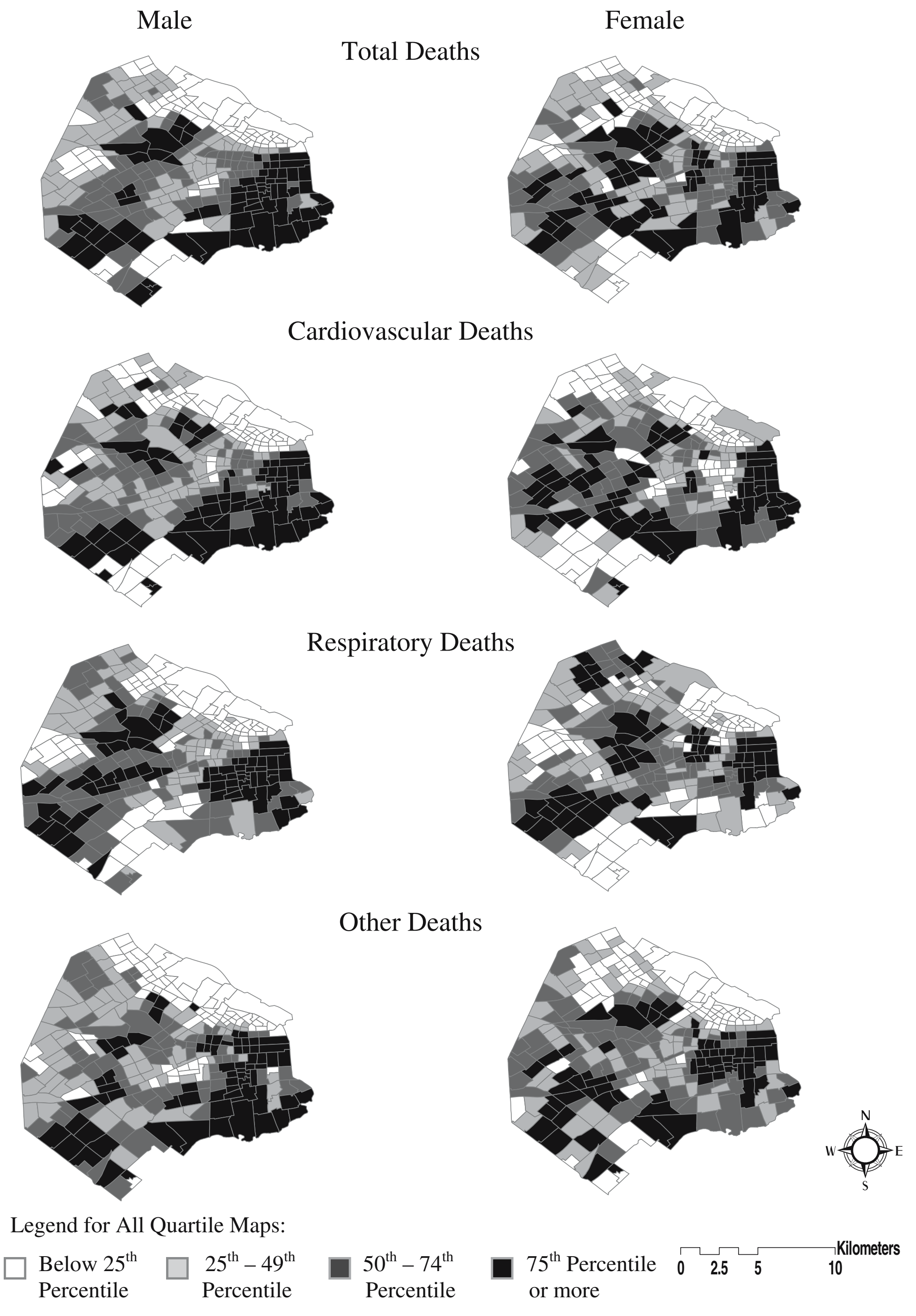

FIGURE 1. Spatially smoothed age-adjusted death rates for total, cardiovascular, respiratory, and other deaths in men and women, city of Buenos Aires, Argentina, 2003. Geographic units shown are censal fractions. Based on spatial empirical Bayes smoothing as indicated in the "Methods" section. *Gray-scale* indicates levels of death rates based on quartiles of the full distribution as indicated in the *legend*.

cardiovascular disease, and other cause mortality show similar patterns, with higher rates in the southern and eastern sections of the city and lower rates in the northern and eastern section. Lower rates are also observed in the southernmost tip of the city. A similar, although less marked, pattern is observed for respiratory deaths, especially in men. This spatial patterning is confirmed by cluster analyses of rates using local Moran's I (Fig. 2). Figure 2 shows clusters of censal fractions with statistically significant ($P < 0.05$) LISA values. Areas labeled as high–high correspond to high-rate areas surrounded by other high-rate areas (clusters of high rates). Areas labeled as low–low correspond to low-rate areas surrounded by other low-rate area (clusters of low rates). High–low corresponds to high-rate areas surrounded by low-rate areas, and low–high corresponds to low-rate areas surrounded by high-rate areas. There is clearly one large low–low cluster in the northern part of the city and two or more clusters of high–high rates in the southern part of the city.

Socioeconomic characteristics were strongly spatially patterned (Moran's I: 0.83). The spatial patterning of socioeconomic characteristics is approximately similar to that observed for death rates, with lower percentages of persons without high school diplomas in the northern and eastern sections of the city and higher percentages in the southern sections (Fig. 3). Table 4 shows relative rates (RR) of death associated with a difference in the socioeconomic indicator equivalent to the difference between the 90th and the 10th percentile value for the census fractions in the city. Percent of residents without high school diplomas was positively associated with death rates from all causes, cardiovascular disease, and other causes of death. Analyses using categorical variables showed that the relationship between censal fraction education and death rates was approximately monotonic (not shown). Among the causes studied, the strongest associations were observed for cardiovascular deaths [RR (95% confidence interval) 1.36 (1.15–1.60) in men and 1.22 (1.01–1.47) in women] and for other causes of death [RR 1.49 (1.20–1.85) in men and 1.63 (1.31–2.03) in women] Weaker and marginally statistically significant associations were observed for respiratory deaths in men. Respiratory deaths in women and neoplasm deaths in men and women were not associated with percent of residents without high school diplomas. Examination of residuals from models with education showed that, although Moran's I values were lower than for models without education (suggesting that education explains at least part of the spatial patterning), spatial patterning remained even after educational differences were accounted for in the case of total deaths in men and women and respiratory deaths in men. Weaker spatial autocorrelation remained for cardiovascular deaths in men and women and for respiratory deaths and other deaths in women.

DISCUSSION

We found evidence of important spatial variation in death rates within the city of Buenos Aires. The strongest spatial patterning was observed for cardiovascular and respiratory deaths in men. Spatial patterning was also observed for cardiovascular deaths in women and for other causes in both men and women. This spatial patterning was closely associated with the spatial patterning of socioeconomic circumstances within the city, although residual spatial autocorrelation often persisted even when area socioeconomic position was accounted for. The most disadvantaged areas of the city had cardiovascular death rates that were 22–36%

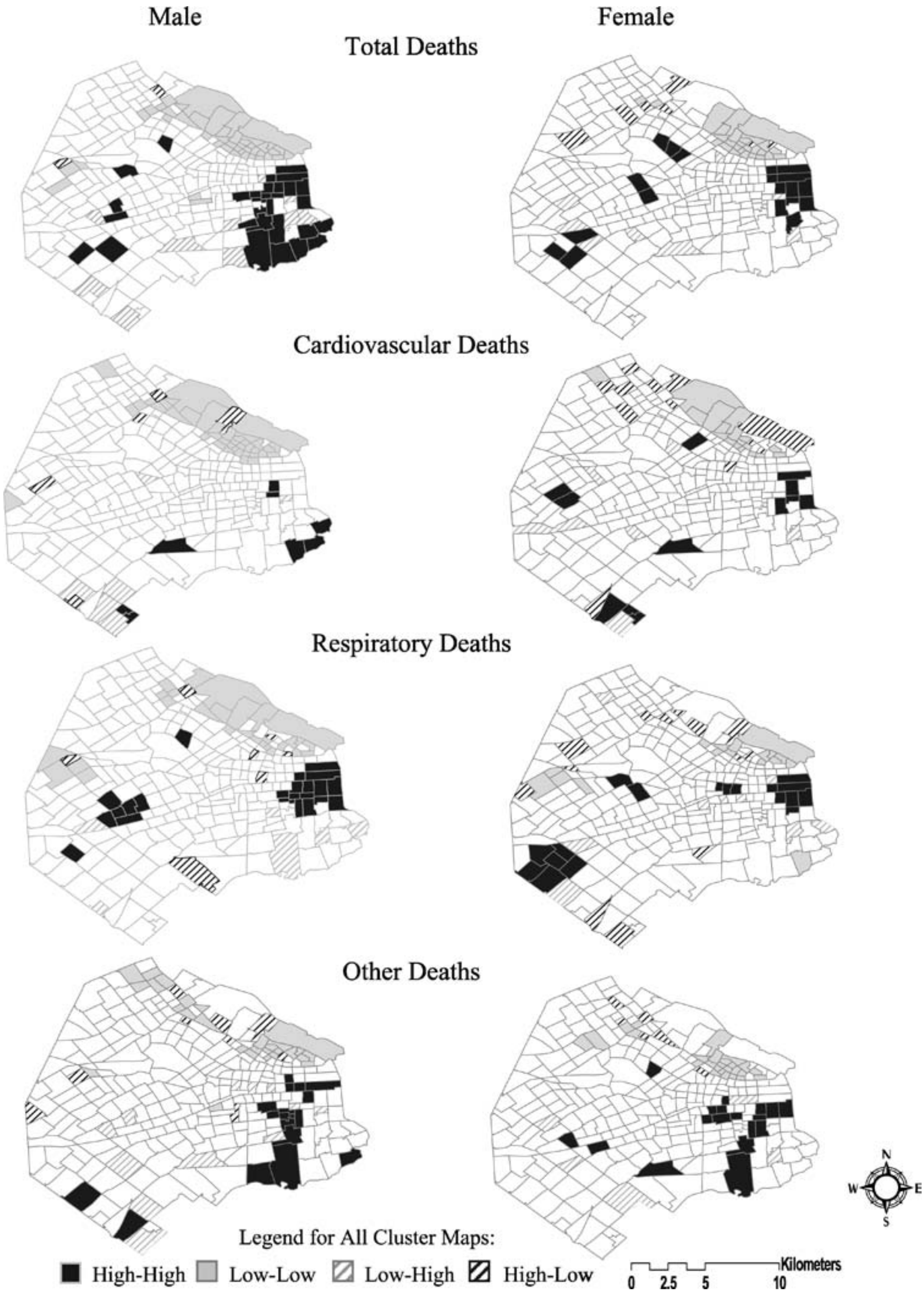

FIGURE 2. Significant clusters of high and low rates for total, cardiovascular, respiratory, and other deaths in men and women, city of Buenos Aires, Argentina, 2003. Clusters of censal fractions with statistically significant ($P < 0.05$) LISA values. Areas labeled as *high–high* correspond to high-rate areas surrounded by other high-rate areas (clusters of high rates). Areas labeled as *low–low* correspond to low-rate areas surrounded by other low-rate area (clusters of low rates). *High–low* corresponds to high-rate areas surrounded by low-rate areas, and *low–high* corresponds to low-rate areas surrounded by high-rate areas.

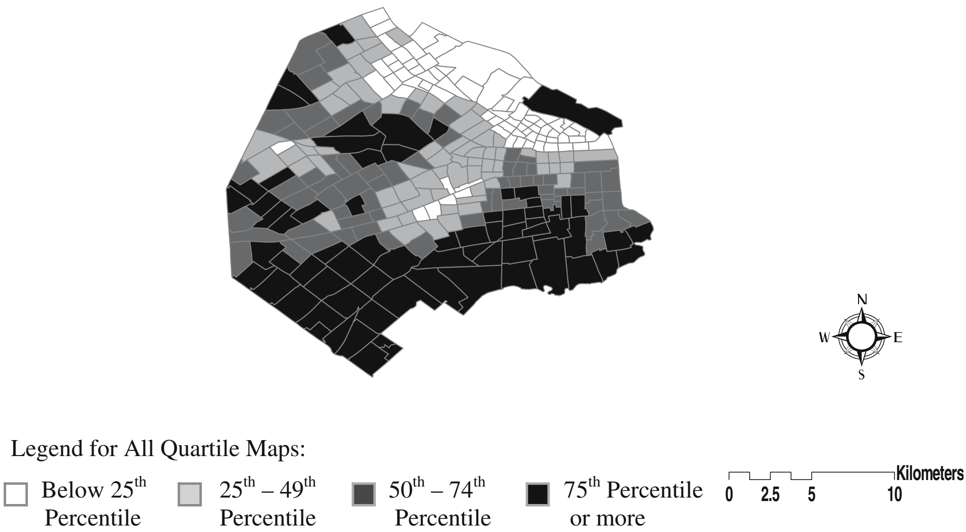

FIGURE 3. Spatial distribution of percent of residents without high school diplomas, city of Buenos Aires, Argentina, 2003. Geographic units shown are censal fractions. *Gray-scale* indicates levels of percent of residents without high school diplomas based on quartiles of the full distribution as indicated in the *legend*.

higher than the most advantaged areas. Similar associations were observed for respiratory deaths in men. Other causes of death were also strongly associated with socioeconomic circumstances (49–63% higher in disadvantaged vs advantaged areas). Although studies in industrialized countries have investigated the spatial and socioeconomic patterning of mortality within cities,[22–24] investigations of this type in developing countries remain rare.

The association of cardiovascular risk with socioeconomic disadvantage has been repeatedly documented in industrialized countries,[25] but data on the social patterning of cardiovascular disease in developing countries are scarce. It has been suggested that the social patterning of cardiovascular disease has shifted over time in industrialized countries, and developing countries may be undergoing a similar process. Our data show that, within a large city in a middle-income country, there is clear evidence that socioeconomic disadvantage is associated with a greater risk of dying of cardiovascular disease, thus countering the common perception that, in these countries, cardiovascular disease is a disease of the affluent.

Poor areas within the city face the burden of increased risk for multiple causes of death. The risk of respiratory deaths was also associated with socioeconomic disadvantage in men, but was not associated with socioeconomic factors in women. This may reflect differential social patterning of smoking in men and women. The group of other causes (which combined infectious disease, external causes, genitourinary causes, unclassified deaths, and various other smaller groups) was also strongly associated with socioeconomic disadvantage. When spatial patterning was present, it was remarkably similar for all causes investigated. This is consistent with other data showing the similar associations of socioeconomic circumstances with many diseases and causes of death. The explanations for this similar patterning include shared socially patterned risk factors and the presence of similar disease processes underlying multiple types of outcomes. This common patterning is

TABLE 4 Relative rates of death associated with the difference between the 90th and the 10th percentile in censal fraction education, Buenos Aires, Argentina, 2003

		95% confidence limits		Moran's I on residuals of model without spatial autocorrelation	
	RR	Lower	Upper	Moran's I	Pseudo *P* value
Males					
Total deaths	1.23	1.09	1.39	0.21	0.001
CVD deaths	1.36	1.15	1.60	0.06	0.044
Respiratory deaths	1.21	0.97	1.52	0.16	0.001
Neoplasm deaths	0.94	0.85	1.04	0.00	0.521
All other deaths	1.49	1.20	1.85	0.04	0.112
Females					
Total deaths	1.24	1.08	1.42	0.14	0.001
CVD deaths	1.22	1.01	1.47	0.05	0.056
Respiratory deaths	1.07	0.85	1.34	0.09	0.007
Neoplasm deaths	1.03	0.87	1.22	0.01	0.325
All other deaths	1.63	1.31	2.03	0.06	0.039

The difference between the 90th and the 10th percentile in censal fraction education is equivalent to the difference between the 90th and the 10th percentile in the city. Relative rates are derived from intrinsic conditional autoregression models as noted in "Methods" section. Moran's Is are based on residuals from a model without spatial autocorrelation

CVD = cardiovascular disease

consistent with the notion that socioeconomic disadvantage affects health through multiple, although interrelated, shared pathways.

An exception to this common pattern was cancer deaths, which were as less clearly spatially patterned and were not associated with socioeconomic circumstances in men or in women. Others have also reported stronger spatial patterning for cardiovascular deaths than for cancer deaths within urban areas.[24] The most common cancer deaths in men were digestive (28.3%), respiratory (23.3%), and genital (13.2%). The most common cancer deaths in women were digestive (27.1%), breast (24.1%), and genital (10.6%). It is plausible that the social patterning of cancer risk factors such as diet and smoking has been different in countries like Argentina than in the USA or Europe, especially when the individuals dying today were in their adolescence and young adulthood. This would result in an absence of the expected inverse gradient for respiratory and digestive cancers associated with these risk factors. A stronger gradient may become apparent as adults today age over time. Breast cancer deaths in women may be positively rather than negatively associated with socioeconomic position due to the social patterning of parity, a major risk factor for breast cancer. This could contribute to the absence of a clear social gradient for neoplasms in women.

The ecological association of area socioeconomic position with mortality likely reflects a combination of the individual-level effects of low socioeconomic position, as well as environmental features associated with poor areas that may have health consequences, including features of both the social and physical environment. It is interesting that at least some spatial patterning remained even when area socioeconomic disadvantage was accounted for. This may reflect socioeconomic differences not captured by the measure we used or other area-level factors.[26]

An important consideration in aggregate analyses like the ones we report is the choice of the appropriate spatial unit for analyses. It is known that the spatial patterning observed may change depending on the spatial scale used (the modifiable areal unit problem).[13] Our choice of censal fractions was based on both theoretical and pragmatic considerations. Censal fractions are approximately homogeneous in socioeconomic characteristics and are therefore appropriate if the research objective is to investigate the socioeconomic patterning of death. From a pragmatic point of view, census data were available aggregated to the censal fraction level, and the average population size of the censal fractions resulted in a sufficient number of deaths per fraction for meaningful analyses. It is possible that the use of smaller geographic units would have allowed us to detect even stronger spatial patterning and stronger associations with socioeconomic position, but it would also have introduced more noise, especially for cause-specific analyses.

Data limitations and data quality are a major challenge in secondary data analyses. The results we report are based on routinely collected data. Causes of death were coded by trained coders following international guidelines; denominators for rates were based on the national censuses. Nevertheless, misclassification of cause of death that undoubtedly occurred could have biased our results. Census undercounts may be more pronounced in socioeconomically disadvantaged areas and could have led us to underestimate associations of death with socioeconomic circumstances. Because intercensal population estimates were unavailable, population counts for 2001 were used as denominators for rates. If differential by area education, changes in population between 2001 and 2003 due to migration could have resulted in biased estimates of associations between area education and mortality. The direction of this bias is difficult to predict in the absence of data on the number, spatial distribution, and health status of migrants. The total population of the city increased by only 3% over the 2-year period, so the impact, if there is any, is likely to be small. Although the number of nongeocoded deaths was small and there was no evidence of systematic differences in geocoded and nongeocoded deaths, at least on the variables available to us, closer examination of the poorer southern areas of the city revealed a larger-than-expected number of nongeocoded deaths. This likely resulted in underestimates of death rates in the southern area. Geocoding errors could also have resulted in underestimates of true associations. Another limitation of our analyses is that, because of data availability, we focused on the core city area and did not include the large metropolitan ring (the greater Buenos Aires area of nearly 11 million people) within which the core city is located. Socioeconomic heterogeneity is much greater for the larger metropolitan area, and thus, substantially stronger spatial and socioeconomic patterning of death is likely to be present.

The growth and evolution of cities, as well as spatial inequalities within them, result from historical and economic forces that structure city development. Beginning in the 1930s and until the late 1970s, the dominant development model in Latin America was that of import substitutions. This model promoted local industrialization through import tariffs and other approaches. The period was characterized by rapid urbanization localized in one or two cities per country, the rapid growth of an industrial working class and a middle class largely employed in services, an increase of "informal" workers, and growing polarization of space within cities as recently arrived workers looking for jobs in the growing industrial sectors settled in peripheral areas and the elite and middle classes began to move out of the core city area into wealthier suburbs, far from the poorer settlements.[27]

A series of political circumstances led to the abrupt end of the import substitution model in the late 1970s and its replacement by a free-market model characterized by liberalization of the economy and foreign trade; privatization of state companies; deregulation of goods, services, and markets; drastic reductions in public spending; and restructuring of social services. This "neoliberal" economic development model was characterized by continued growth of urban population (although no longer as concentrated in a single city), increases in unemployment and underemployment, deterioration of working conditions, and marked increases in poverty and inequality. Increases in unemployment and underemployment and associated increases in poverty and inequality were particularly stark in Buenos Aires, where the percent of persons living below the poverty level increased from 5% in 1980 to 34% in 1990 and 52% in 2002/2003.[27,28] The spatial and social inequalities in death that we report are one of the outcomes of these historical and economic processes, which affect not only people's life opportunities, but also their health and longevity.

In summary, we found evidence of substantial intraurban variation in risk of death within a large city in a middle-income country. This spatial variability was partly explained by the spatial patterning of socioeconomic disadvantage, was present for multiple causes of death, and was strongest for cardiovascular disease. Our results highlight the pervasive role of space and social inequalities in shaping life and death within large cities.

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