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Amenable Mortality and Neighborhood Inequality: An Ecological Study of São Paulo

Irina B. Grafova, Daniel Weisz, Rafael Fischetti Ayoub, Victor G. Rodwin, Rachel NeMoyer, and Michael K. Gusmano

This article uses an ecological study design to explore intraurban health inequality in São Paulo by examining neighborhood-level changes in mortality amenable to medical care. We use 2003–2013 data for 95 city districts of São Paulo and apply a random coefficient growth curve modeling approach. We find that improved access to health-care services is associated with reduced amenable mortality. Despite these overall improvements, the magnitude of population health disparities, as measured by amenable mortality, did not diminish. The effects of social, economic, and health system factors on amenable mortality depend on the income level of the district. Persistent disparities in amenable mortality within São Paulo suggests that neighborhood-level differences in social determinants of health and access to health services require further investment from the Brazilian government.

KEY WORDS: amenable mortality, neighborhood inequality, health systems

Este documento utiliza un diseño de estudio ecológico para explorar la desigualdad de salud intraurbana en São Paulo al examinar los cambios en el nivel de vecindad en la mortalidad susceptible de atención médica. Utilizamos datos de 2003-2013 para 95 distritos de la ciudad de São Paulo y aplicamos un enfoque de modelado de curva de crecimiento de coeficiente aleatorio. Encontramos que un mejor acceso a los servicios de salud está asociado con una reducción de la mortalidad susceptible. A pesar de estas mejoras generales, la magnitud de las disparidades de salud de la población, medida por la mortalidad susceptible, no disminuyó. Los efectos de los factores sociales, económicos y del sistema de salud sobre la mortalidad aceptable dependen del nivel de ingresos del distrito. Las disparidades persistentes en la mortalidad susceptible dentro de São Paulo sugieren que las diferencias a nivel de vecindario en los determinantes sociales de la salud y el acceso a los servicios de salud requieren una mayor inversión del gobierno brasileño.

PALABRAS CLAVE: mortalidad aceptable, desigualdad en el vecindario, sistemas de salud

本文使用一项生态学研究设计, 通过检验可通过医疗而避免的死亡率在邻区层面的变化, 探究圣保罗市内区域的卫生不平等。我们使用2003年至2013年期间圣保罗95个城市区域的数据, 并应用一项随机系数增长曲线模型法。我们发现, 医疗服务获取性的改善与可避免死亡率下降相关。除去这些整体提升, 由可避免死亡率进行衡量的人口卫生不平等程度却没有降低。社会因素、经济因素和卫生系统因素对可避免死亡率产生的效果取决于该区域的收入程度。圣保罗市可避免死亡率的持续差异暗示, 邻区在卫生的社会决定因素与卫生服务的获取方面的差异要求巴西政府进行更多投资。

关键词： 可避免死亡率, 邻区不平等, 卫生系统

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Introduction

Rapid urbanization, worldwide, generates neighborhood inequalities that affect health-care systems and public health in ways that we have only recently begun to disentangle. We still need to improve our understanding of how national and local policies, as well as neighborhood-level physical and social environments, affect population health and intraurban health inequalities (Angeles, Ahsan, Streatfield, Arifeen, & Jamil, 2019; Grafova, Gusmano, Martirosyan, Weisz, & Rodwin, 2019; Gusmano, Weisz, Allende, & Rodwin, 2019; Smit et al., 2011). In this article, we explore intraurban health-care inequalities in São Paulo by examining neighborhood-level changes in mortality amenable to health care and how social, economic, and health system factors shape these changes. Among middle-income nations, Brazil is one of the most urbanized and São Paulo is the most populous metropolitan area in the entire Southern Hemisphere (Population Division, 2018).

Previous studies that explore intraurban health inequalities in São Paulo have documented strong socioeconomic inequalities in population health. They have focused on mobility limitation and falls among older adults (Nascimento, Duarte, Lebrão, & Filho, 2018); sepsis deaths (Diament et al., 2016); stroke mortality (Fernandes, Bando, Alencar, Benseñor, & Lotufo, 2015; Kaup et al., 2015); and mortality from nonaccidental, cardiovascular, and respiratory illnesses (Bravo, Son, Umbelino de Freitas, Gouveia, & Bell, 2015). Bravo et al. (2015) link 1996–2010 mortality data with air pollution and weather data from 17 city air pollution monitors. They find that a higher level of exposure to particulate matter with an aerodynamic diameter $\leq 10\,\mu m$, nitrogen dioxide, sulfur dioxide, and carbon monoxide is associated with increased risk of nonaccidental, cardiovascular, and respiratory mortality. Fernandes et al. (2015) analyze stroke mortality rates within São Paulo, over the 1996–2011 period, among individuals aged 35–74 years old. Although they find that the risk of stroke mortality is decreasing in all neighborhoods, they observe that the more rapid decline in the wealthiest areas may exacerbate health inequalities. Another study, by Kaup et al. (2015), also finds a strong socioeconomic gradient in the rate of decline in stroke mortality. Diament et al. (2016) analyze 2004–2009 deaths due to sepsis in São Paulo and find a strong association with poverty. Nascimento et al. (2018) find that high educational attainment and availability of green spaces serve as protective factor for mobility impairment.

This body of research documents important differences in health status, among neighborhoods in São Paulo. Few studies, however, have explored the consequences of neighborhood-level differences in access to health care. We rely on a measure of access to effective health care—amenable mortality (AM)—that focuses on premature deaths due to causes for which there are effective health-care interventions. Our analysis builds on work published in 2016, which found a significant reduction in the overall rate of AM in São Paulo between 2000 and 2010 (Gusmano, Rodwin, Weisz, & Ayoub, 2016). Although most scholars of health systems and policy emphasize the importance of social determinants of health, most recognize that health care can prolong life "after some serious diseases" (Vergara-Duarte et al., 2018; Weisz, Gusmano, Rodwin, & Neuberg, 2008).

For example, the use of antibiotics and other pharmaceutical interventions, advances in surgical and anesthetic techniques, and antenatal and perinatal care have all contributed significantly to mortality declines (Mackenbach, 1996; Vergara-Duarte et al., 2018). Nolte and McKee have examined AM in several countries and conclude that health care makes an appreciable difference to population health (Nolte & McKee, 2004, 2012). AM is an important dimension of the health system performance that has been widely adopted in Canada, New Zealand, Australia, and Europe (Alkire, Peters, Shrime, & Meara, 2018; James, Wilkins, Detsky, Tugwell, & Manuel, 2007; Korda, Butler, Clements, & Kunitz, 2007; Stirbu et al., 2010; Tobias & Jackson, 2001; Younger & Moon-Howard, 2016). Although this measure has been used frequently to compare health systems (Alkire et al., 2018), few studies have applied it at the neighborhood level (Borrell, Mari-Dell'olmo, Serral, Martinez-Beneito, & Gotsens, 2010; Gusmano et al., 2014; Hoffmann et al., 2014; Nolasco et al., 2009; Weisz, Gusmano, Rodwin, & Neuberg, 2007).

With the exception of Weisz et al. (2007); Chau, Woo, Chan, Weisz, and Gusmano (2010); and Gusmano et al. (2014, 2016), who have focused on world cities, most neighborhood-level studies focus on European cities. Their principal finding is that area socio-economic deprivation partially explains mortality inequalities across neighborhoods. Use of the AM measure, to compare neighborhoods in São Paulo, provides a unique perspective on the role of socioeconomic, as well as health system factors, in shaping health inequalities.

The Brazilian Health and Social Welfare System

Brazil has a mixed public and private health system. The universal public health system, Sistema Único de Saúde (SUS), established in 1989, covers both inpatient and outpatient care. Economic growth and political changes enabled the government to expand SUS over the decade 2003–2013 (Massuda, Hone, Leles, de Castro, & Atun, 2018). Between 2003 and 2011, total health-care expenditure increased from 7 percent to 9 percent of gross domestic product (GDP). Government spending, as a share of total health-care expenditure, reached 45 percent in 2011.

A key part of SUS, Programa Saúde da Família (Family Health Strategy [FHS]), was created in 1994 and aimed to provide primary health care to underserved populations (Macinko & Harris, 2015). FHS provides care in an interdisciplinary setting by employing family health teams that are typically composed of a doctor, a nurse, nursing assistants, and several community health workers. It has undergone rapid expansion during the 2000s. In 2003, there were 515 FHS teams in São Paulo; and by 2012, 1,225 FHS teams (SãoPaulo, 2013).

In addition to the SUS, approximately 25 percent of Brazilians (60 percent in São Paulo), have some type of supplementary private health insurance, and the number increased over the 2000–2012 period (Macinko & Harris, 2015). Poor families are less likely than middle- or high-income families to seek health care in the private sector (Macinko & Harris, 2015). In São Paulo, about 3 million people, of the 11.5 million population, rely exclusively on the private sector for their care. Another 4 million people, with some form of private health insurance, use the SUS system for services not covered by their insurance, or when the required specialized services are only available in public hospitals.

Bolsa Família—Conditional Cash Transfer Program

In 2003, Brazil established Bolsa Família—a conditional cash transfer program designed to address poverty. Benefit levels depend on household size and income. From 2003 to 2013, the number of households receiving Bolsa Família payments increased from 3.6 million to 13.8 million. By the end of this period, according to the Centro de Geoprocessamento e Estatística, the program covered nearly a quarter of Brazil's population; in São Paulo, payments doubled from R$ 72.33-144.91.

Methods

Data Sources

São Paulo is divided into 32 boroughs and 96 districts. We rely on the districts (Bravo et al., 2015; Fernandes et al., 2015; Kaup et al., 2015) as proxies for neighborhoods. The data in this study come from three sources: DATASUS, a database maintained by the Department of Informatics of the Brazilian Health System (Ministério da Saúde, 2014); Infocidade, a data portal maintained by the Municipal Department of Urban Development of São Paulo (Prefeitura Municipal de São Paulo, 2017); and the Brazilian Institute of Geography and Statistics (IBGE, 2014). Data on disease-specific mortality, health center attendance, and prenatal care use are from DATASUS. District-level data on sewage availability, murder rate, literacy, and district average income are from Infocidade. Data on Bolsa Família program and district population sizes are from Brazilian Institute of Geography and Statistics.

District Characteristics. We measure health-care access within districts based on the number of visits to health centers per 20,000 population per year (hereafter referred to as health center attendance) and by the percentage of births for which a mother recorded no prenatal care visits. We measure educational attainment of district residents, based on the percent of illiterate individuals aged 15 years or more. As a measure of social conditions, we supplement education attainment variables with a measure reflecting the percent of district households without sewer connections. We also include a measure of social disorganization: whether the annual district murder rate is below 2 per 10,000 population. Finally, we also rely on two measures of neighborhood income: (1) the percentage of district households receiving Bolsa Família cash welfare payments (available since 2006); and (2) the percent of households with income greater than 10 times the minimum wage (available for the year 2000 only).

Amenable Mortality. AM reflects premature deaths from causes for which there are effective public health and health-care interventions. Consistent with previous research (Gusmano et al., 2016), this analysis focuses on all premature (under age 75) registered deaths and relies on Nolte and McKee's definition of AM (Nolte & McKee, 2008). For São Paulo, we obtained disease-specific mortality data for each district from the Brazilian National Mortality Information System (Ministério da Saúde, 2014). To age-adjust these data, we employed the direct method (Klein & Schoenborn, 2001), using weights derived from the 2010 United Nations world standard population (United Nations, 2019).

Sample. Our sample includes 95 of the 96 districts. We exclude the district of Marsilac for two reasons: (1) It is located in the extreme south tip of the city, relatively far from where the vast majority of São Paulo's population lives; (2) It exhibits unusually high variation, over time, in its levels of AM rates and socioeconomic disadvantage. Following Wooldridge and Verbek (Verbeek, 2017; Wooldridge, 2012), we conducted regression analysis on both the entire sample and one that excluded Marsilac. Including Marsilac in the sample analysis does not alter the statistical significance of the estimated associations but it changes their estimated magnitude by as much as 60 percent. We, therefore, concluded that Marsilac biased the regression estimation results and opted to exclude it from our analysis.

Statistical Analyses. Using data for 95 city districts, we describe AM rates by district and examine differences, based on *t* tests, between economic, demographic, health system, and social characteristics of districts. To examine the relationship between AM and district characteristics, we use a random coefficient growth curve modeling approach. Growth curve models allow for exploration of both intradistrict changes and district level differences in the nature of the change. Using this approach, time points (Level 1) are nested with districts (Level 2). Since we use 2003–2013 data, each district (Level 2) is observed at 11 time points (Level 1). To improve interpretation of the models, we "centered" the variable reflecting year of observation in 2003, so that the growth curve intercept for each district represented their baseline AM in 2003. We built the growth curve model in two steps (Curran, Obeidat, & Losardo, 2010; Raudenbush & Bryk, 2002). First, we explored how the repeated measures of AM change over time, identifying the optimal functional form of the trajectory. Second, we incorporated predictors into the model. We include both time-invariant covariates and time-varying covariates. Below we describe the elements of the model in more detail.

To capture the optimal functional form of the trajectories of AM, we compare random intercept and random coefficient unconditional models using Akaike and Bayesian information criteria and the likelihood ratio test. It appears that a random coefficient model provides the best fit. Next, we compare trends of linear and quadratic functions over time. It appears that the linear model is the best fit, which suggests that AM changed uniformly over time.

Having identified the optimal functional form of the trajectory over time, we incorporated predictors into the model. To develop a level-1 model that accurately reflects the shape of the AM trajectory, we incorporated several time-varying predictors in the model. These include health-care access, educational attainment, social conditions, and the social disorganization measure noted earlier. To examine intra-district variability in AM, we introduced level-2 predictors reflecting district baseline economic status. Finally, to allow for health-care access, prenatal care, and education to affect the shape of the AM trajectory for low-, middle-, and high-income districts, we add dummy variables for middle- and high-income districts as predictors for the slopes of these variables.

The slopes of the time-varying variables are estimated as fixed rather than as random. Random slopes allow predictors to have a different effect for every district while fixed slopes assume the same slope across districts. Raudenbush and Bryk (2002) caution against estimating all slopes as randomly varying by default: "if one overfits the model by specifying too many random level-1 coefficients, the variation is partitioned into many little pieces, none of which is of much significance" (p. 256). Following McCoach and Kaniskan (2010) we re-estimate the final model assuming random rather than fixed slopes for π_{2i}- π_{7i}. Because it did not improve the model fit and tended to result in model overfitting, we decided in favor of fixed slopes. Thus, our final model for predicting AM_{it} in district i in year t can be written as:

$$\text{Level 1: } AM_{it} = \pi_{0i} + \pi_{1i}Time_{it} + \pi_{2i}Health\_care\_access_{it} + \pi_{3i}Prenatal\_care + \pi_{4i}Education + \pi_{5i}Bolsa\_Família_{it} + \pi_{6i}NoSewer + \pi_{7i}Murder\_rate + \varepsilon_{it},$$

$$Level\ 2\text{: } \pi_{0i} = \beta_{00} + \beta_{01}Middle\_income_i + \beta_{02}High\_income + r_{0i};$$

$$\pi_{1i} = \beta_{10} + r_{1i};$$

$$\pi_{2i} = \beta_{20} + \beta_{21}Middle\_income_i + \beta_{22}High\_income;$$

$$\pi_{3i} = \beta_{30} + \beta_{31}Middle\_income_i + \beta_{32}High\_income;$$

$$\pi_{4i} = \beta_{40} + \beta_{41}Middle\_income_i + \beta_{42}High\_income;$$

$$\pi_{5i} = \beta_{50}; \pi_{6i} = \beta_{60}; \pi_{7i} = \beta_{70}.$$

This model enables us to test the hypotheses on whether district characteristics predict the initial level of AM and its rate of change over time.

We conducted two sensitivity tests. Following Rabe-Hesketh and Skrondal (2008), we re-estimated the regression model as a fixed-intercept model and as a random-intercept model. The sensitivity test estimation results were similar to the random coefficient model results described below.

Results

In 2003, the average São Paulo district had an AM rate of 1.31 that varied by district type. In low-income districts, the AM rate was more than one and a half times greater than in high-income districts. During the 2003-2013 period, AM in the average São Paulo district fell to 1.08. Figure 1 shows that this decline was similar across districts of different income levels.

To shed light on to the question of why such persistent differences in AM are observed across São Paulo, we compared the characteristics of low-, middle-, and high-income districts. Table 1 indicates that social conditions, as reflected by availability of sewers, literacy rates, and murder rates, improved dramatically across districts over the 2003–2013 period. For instance, in low-income districts, the share of households without sewers fell nearly in half. In 2003, only 3 percent of low-income districts had a murder rate below 2 per 10,000 population. In 2013, 77 percent of low-income districts decreased in that category. The share of those who are illiterate, among residents aged 15 years or older, decreased by 30–40 percent across all district types with the highest decline occurring in high-income districts.

Table 1 also shows that access to prenatal care improved over the study time period. The share of births to mothers who did not obtain prenatal care fell in both

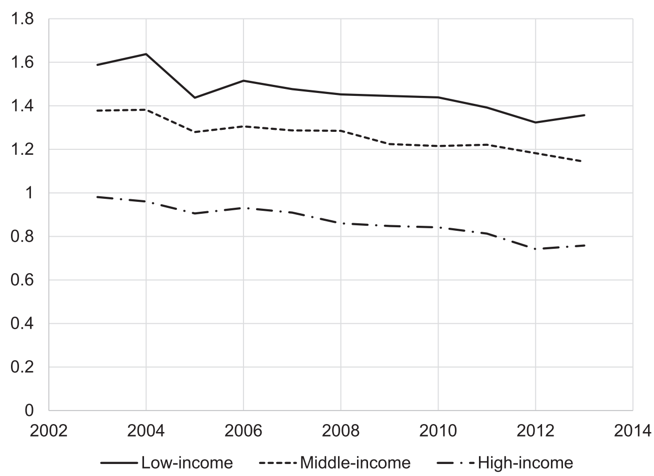

Figure 1 Mean District-Level Amenable Mortality by District Type. Ninety-Five Districts of São Paulo Are Included.

Table 1. District-Level Economic, Health-Care, and Social Conditions in São Paulo, 2003 and 2013

	All districts		Low-income districts		Middle-income districts		High-income districts	
	2003	2013	2003	2013	2003	2013	2003	2013
Amenable mortality	1.31	1.08§§	1.59	1.36**	1.38	1.14$^{\#\#}$	0.98	0.76††
Economic								
% households receiving Bolsa Família payments	0	5.95§§	0.00	9.65**	0.00	5.56$^{\#\#}$	0.00	2.76††
Health care								
% births with no prenatal care	1.67	1.26§§	1.95	1.35**	1.83	1.66	1.24	0.78††
Health center attendance per 20,000 population	0.74	0.75	0.73	0.94**	0.92	0.83	0.57	0.49
Social conditions								
% illiterate among 15+ y.o.	3.61	2.35§§	5.67	3.80**	3.58	2.35$^{\#\#}$	1.66	0.94††
% of households with no sewer	9.43	5.13§§	20.39	10.45**	6.34	3.77$^{\#}$	1.89	1.34
Murder rate below 2 per 10,000 population, %	22.11	91.58§§	3.23	77.42**	6.25	96.88$^{\#\#}$	56.25	100.0††

Note: 95 districts of São Paulo are included.
2013 district characteristic is statistically different from 2003 low-income district characteristics at $^{§§}p < .01$.
2013 low-income district characteristic is statistically different from 2003 low-income district characteristics at $^{*}p < .05$ and $^{**}p < .01$.
2013 middle-income district characteristic is statistically different from 2003 middle-income district characteristics at $^{\#}p < .05$ and $^{\#\#}p < .01$.
2013 high-income district characteristic is statistically different from 2003 high-income district characteristics at $^{††}p < .01$.

low- and high-income districts and remained stable in middle-income districts. The public health center attendance rates did not change significantly for residents of middle- or high-income districts. However, the average number of visits to health centers, among residents of low-income districts, increased over the study period.

To examine how the introduction of Bolsa Família, which did not exist at the beginning of the study time period, along with improvements in the public health-care system and changes in the social environment, may have affected AM, we conducted multivariate regression analysis using a random coefficient growth curve modeling approach. The estimation results are presented in Table 2.

Table 2. Amenable Mortality in São Paulo: Random Coefficient Growth Curve Model Analysis

	Model 1	Model 2	Model 3
Fixed part			
Intercept	1.3101 (0.0343)**	1.4339 (0.0947)**	1.5442 (0.1112)**
Linear year trend	−0.0231 (0.0017)**	−0.0202 (0.0027)**	−0.0178 (0.0028)**
Economic			
Middle-income districts		−0.1547 (0.0574)**	−0.3334 (0.1232)**
High-income districts		−0.5069 (0.0733)**	−0.7457 (0.1129)**
Households receiving Bolsa Família payments		0.1369 (0.1649)	0.1480 (0.1671)
Health care			
Health center attendance		−0.0204 (0.0264)	−0.1336 0.0438)**
Health center attendance among middle-income districts residents			0.1765 (0.0669)**
Health center attendance among high-income districts residents			0.1666 (0.0616)**
% births with no prenatal care		2.3445 (0.7975)**	3.7690 (1.9070)*
% births with no prenatal care among middle-income districts residents			0.3131 (2.1972)
% births with no prenatal care among high-income districts residents			−5.6210 (2.3852)*
Social conditions			
% illiterate among 15+ y.o.		1.7308 (1.6542)	0.5453 (2.0075)
% illiterate among 15+ y.o. in middle-income districts			0.1449 (2.3019)
% illiterate among 15+ y.o. in high-income districts			11.2011 (3.4250)**
% of households with no sewer		0.1451 (0.1985)	0.2462 (0.2068)
Murder rate below 2 per 10,000 population		0.0023 (0.0124)	0.0011 (0.0124)
Random part			
$\sqrt{\varphi_{11}}$	0.33	0.20	0.19
$\sqrt{\varphi_{22}}$	0.01	0.01	0.01
ρ_{21}	−0.22	−0.30	−0.29
SD of residuals	0.12	0.12	0.12
Number of years	11	11	11
Number of districts	95	95	95

Note: Standard errors in parentheses. Year trend variable is centered at 2003. All models are random coefficient growth curve models estimated via maximum likelihood. Sample includes 95 districts of São Paulo.

*$p < .05$.

**$p < .01$.

Model 1 estimates that the average annual decline in AM rate was about 0.02 but contains no additional regressors. Model 2 adds economic, social, and health-care access characteristics into the regression. The results indicate that AM was lower in middle- and high-income districts compared with low-income districts. This is consistent with the descriptive analysis results presented above. The results also indicate that having a higher share of births, with no prenatal care for mothers, is associated with a higher AM rate. Notably, the results indicate no statistically significant relationship between Bolsa Familia and AM.

To account for the fact that educational attainment and health-care system factors may have differential impacts on residents in low-, middle-, and high-income districts, we augment Model 3 with interaction terms. The estimation results support the differential role of education and health care across districts. To better interpret Model 3 estimation results, we used these results to predict district AM change associated with changes in literacy, prenatal care use, and public health system use. Specifically, we predicted the impact associated with changes in literacy, prenatal care use, and public health system use from the 25th to 75th percentiles (see Figure 3). The results show the increasing attendance of health centers among low-income districts residents from the 25th to 75th percentile and a decreased AM rate by 0.05. There is no statistically significant association between health center attendance and AM among residents in middle- and high-income districts. Increasing the rate of prenatal care use from 25th to 75th percentile decreased the AM rate among low- and middle-income districts residents by 0.03 and had no statistically significant effect on residents of high-income districts. However, increased literacy rates are predicted to improve significantly AM in high-income districts. This is consistent with the hypothesis that illiterate residents from high-income districts may be particularly disadvantaged due to high inequality relative to other residents of high-income districts.

Discussion

Our findings indicate that all residents of São Paulo, across all neighborhoods, experienced improvements in population health and access to health-care services that may have helped to reduce AM over the 2003–2013 period. Despite these improvements, the magnitude of population health disparities, as measured by AM, did not diminish. Figure 2 shows that substantial intra-city variation in AM rates, across districts, remained at the end of this period. Moreover, it shows that certain areas of the city have consistently higher or lower rates of AM in comparison with the average.

We also find that the effects of social, economic, and health system factors on AM depend on the income level of the district. In this regard, it is surprising that income support (Bolsa Família payments) for the most deprived city residents, had no statistically significant effect on AM. Previous studies have reported that Bolsa Família increased the use of health-care services (Shei, Costa, Reis, & Ko, 2014) and reduced childhood mortality (Rasella, Aquino, Santos, Paes-Sousa, & Barreto, 2013). It is possible that the lack of statistical significance in the estimated association

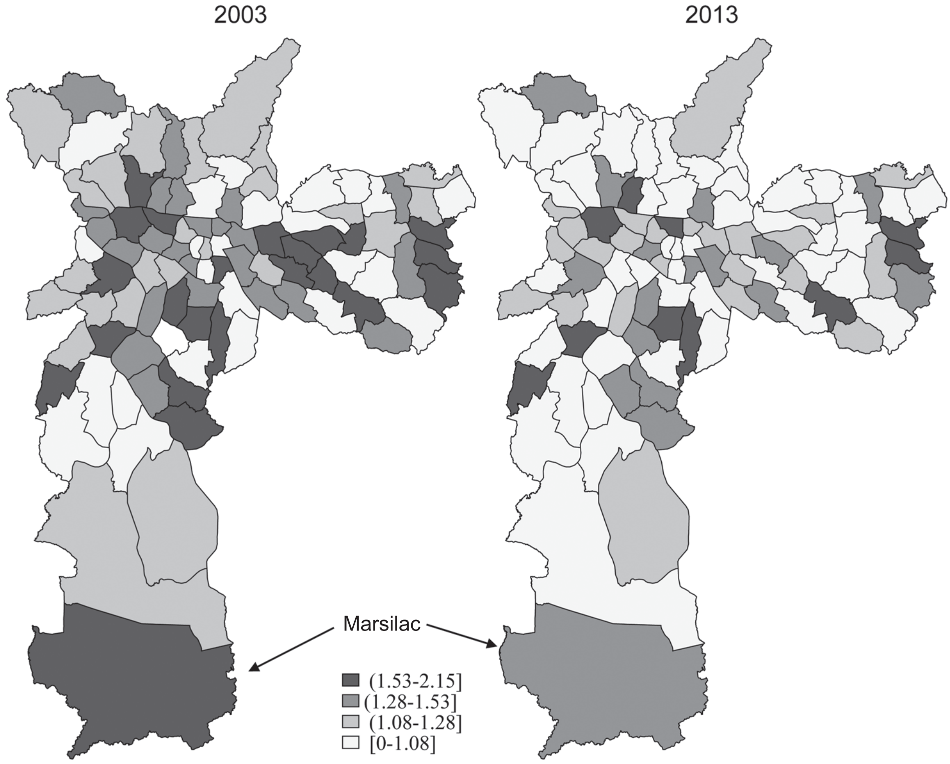

Figure 2 Amenable Mortality in São Paulo by District: 2003 and 2013.

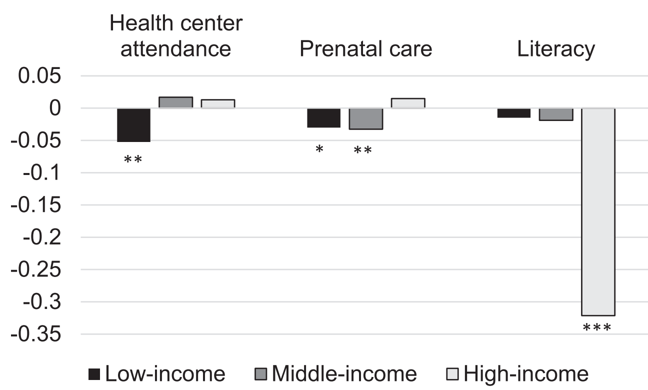

Figure 3 Predicted Association Between Changes In Literacy, Prenatal Care Use, and Public Health System Use and Amenable Mortality. *$p < .05$; **$p < .01$. This figure presents predicted changes in district amenable mortality when literacy, prenatal care use, and public health system use changes from 25th to 75th percentile holding all other variables set at the means. The chart is based on model 3 in Table 2 above.

between Bolsa Família and AM is caused by the relatively small sample size. Our sample includes 1,045 district-year observations and our analysis may lack the requisite statistical power to detect the impact of Bolsa Família. The aggregate nature of the data we use may also contribute to the lack of statistical significance (Loney & Nagelkerke, 2014; Thiese, 2014).

Residents in high-income districts are more likely to have access to the private health-care system while residents in low-income districts are more likely to rely primarily on the public health-care system. Thus, improved access to the public health-care system is more likely to improve health outcomes of low-income district residents than of high-income district residents. Our findings are consistent with this hypothesis. We find that increased use of public health clinics is associated with reductions in AM among residents of the lower-income districts of the city but is not associated with changes in AM in the middle- and high-income districts. Thus, it is important to protect and expand access to public health systems, especially, in low- and middle-income neighborhoods.

Similarly, residents in high-income districts tend to have higher educational attainment than residents in low-income districts. Thus, the association between literacy and AM, in high-income neighborhoods, could potentially be explained by illiterate residents being more likely to be socially isolated in high-income districts than in low-income districts. If so, improved literacy is more likely to improve health outcomes of high-income district residents than that of their counterparts in low-income districts. This highlights the potential role that relative deprivation plays in shaping poor health outcomes. From a policy perspective, this result suggests that to improve population health we ought to adopt a strategy that targets individuals who need additional support.

An important limitation of our study is the use of district-level rather than individual-level data. The district-level data may be subject to inaccuracies (Thiese, 2014). For instance, district health-care use data cannot identify what proportion of district clinic visits were due to residents of other districts. Moreover, we cannot account for potential confounders, such as self-selection into the particular neighborhoods of residence. Also, due to our ecological study design, observed associations could potentially be biased by the ecological fallacy (Loney & Nagelkerke, 2014). The use of district-level data also limits our sample size.

Conclusion

Little is known about the consequences of neighborhood-level differences in access to health care, but this study makes an initial contribution. We find that there were significant reductions in AM across neighborhoods over time, including among the poorest neighborhoods of São Paulo. This suggests that population health can be improved through investments in social and economic determinants of health, as well as by direct investments in the health-care system. Nevertheless, the persistent inequalities in AM within São Paulo, which we have documented, suggest that district-level differences in the social determinants of health and the health-care system require further investment from the Brazilian government.

Notes

Conflicts of interest: None declared.
Corresponding author: Irina B. Grafova, grafovib@sph.rutgers.edu

Irina B. Grafova, PhD, is an assistant professor at Rutgers University School of Public Health.

Daniel Weisz, MPA, MD, a research associate at the Butler Columbia Aging Center at the Mailman School of Public Health at Columbia University.

Rafael Fischetti Ayoub, MD, MPA, is the director of clinical service line at Ready Responders.

Victor G. Rodwin, MPH, PhD, is a professor of health policy and management, Robert F. Wagner Graduate School of Public Service, New York University.

Rachel NeMoyer, MPH, MD, is a general surgical resident at Rutgers Robert Wood Johnson Medical School at Rutgers University.

Michael K. Gusmano, PhD, is an associate professor at Rutgers University School of Public Health and a research scholar at the Hasting Center.

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