

Short Communication

Spatiotemporal patterns of AIDS incidence among adults in São Paulo, Brazil

Elisangela Aparecida da Silva Lizzi^[1], Altacílio Aparecido Nunes^[2]
and Edson Zangiacomi Martinez^[2]

[1]. Departamento de Matemática, Universidade Tecnológica Federal do Paraná, Cornélio Procopio, PR, Brasil.

[2]. Departamento de Medicina Social, Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo, Ribeirão Preto, SP, Brasil.

Abstract

Introduction: AIDS remains a major public health concern in Brazil. **Methods:** This study investigated spatiotemporal patterns of reported AIDS cases among adults in São Paulo between 2000 and 2016, and their associations with human development index. **Results:** In the early 20th century, the more developed administrative districts (ADs) indicated higher AIDS incidences among men. From the 2010s, ADs with lower development indicate higher rates of the disease among women. **Conclusions:** The results are useful to support the planning of actions aimed at controlling the incidence and transmission of AIDS in certain areas, based on diversification by gender and risk populations.

Keywords: AIDS. Epidemiology. Spatial modelling.

The dynamics of the AIDS epidemic in large populations are highly complex and can result in several regional sub-epidemics defined according to different social interactions. In this context, spatial studies have been applied to understand the characteristics of the dynamics of AIDS in Brazil^{1,2} using geoprocessing methods integrated with spatial statistical models³. Spatial epidemiology statistical methods provide resources to explore the spatial location of events, facilitated by the use of geographic information systems, allowing identification, location, and visualization of the occurrence of phenomenon of interest. Spatial studies on this occurrence in a given population (e.g.,¹⁻⁴) allow the understanding of its spatial distribution and constitute an effective tool to optimize public health strategies by allocating resources according to each region's needs⁴.

The objective of this article is to study the spatial and temporal distribution of notified AIDS cases among adults (18 years old or more) in São Paulo, between 2000 and 2016, and their associations with the Human Development Index (HDI) and its three components: education, income, and life

expectancy. Open-access data from the Brazilian HealthCare Computer System (DATASUS) regarding the number of new cases of AIDS recorded from 2000 to 2016 in each of São Paulo's administrative districts (AD) were gathered. São Paulo is the most populated city in South America with more than 12 million inhabitants. The city is divided into 96 ADs based on geographical and administrative features. Data on HDI (year 2000) were obtained from the Atlas of Human Development in Brazil.

Let Y_{itk} be the number of incident cases of AIDS observed in the i -th AD ($i = 1, \dots, 96$) in the year t ($t = 1$ if 2000, $t = 2$ if 2001, ..., $t = 17$ if 2016), considering individuals by gender k ($k = 1$ if males and $k = 2$ if females). The statistical model considers that Y_{itk} is a random variable that follows a Poisson distribution with mean value given by $N_{itk}\theta_{itk}$, where N_{itk} is the number of inhabitants of the i -th AD in the year t and gender k , and θ_{itk} is an unknown parameter to be estimated relative to the incidence rate for each AD, year, and gender. Two different models were fitted.

Model 1: This model was defined in order to obtain spatially smoothed incidence rates of the disease, where $\ln(\theta_{itk}) = \alpha_k + \lambda_{ki} + W_{itk}$. In this formulation, α_k is an intercept for each gender ($k = 1, 2$) following a flat prior distribution and λ_{ki} ($k = 1, 2$, $i = 1, \dots, 96$) are random effects capturing the possible spatial correlations among the AIDS incidences, considering the effects of neighboring fields. A bivariate intrinsic conditional autoregressive (CAR) normal structure was assigned to λ_{ki} , where

Corresponding author: Edson Zangiacomi Martinez.

e-mail: edson@fmrp.usp.br

Orcid: 0000-0002-0949-3222

Received 19 January 2018

Accepted 29 November 2018

the neighborhood was defined by the adjacency criterion⁵. Finally, W_{itk} are longitudinal effects for the incidence rates, following multivariate normal distributions with a mean vector of zero and variance matrix with components described in Branscum et al.⁶.

Model 2: This model included a covariate denoted by X based on the function $\ln(\theta_{itk}) = \alpha_{kt} + \lambda_{ki} + \beta_{kt}(x_i - m)$, where α_{kt} are constant intercepts for each gender and year, λ_{ki} are spatial random effects defined in Model 1 and parameters β_{kt} measure the effect of covariate X on the incidence rate for each gender and year. Further, x are observations of X and m is the mean of these observations. It is not possible to fit multiple models to the data, simultaneously including all HDI components, due to high collinearity among these variables. Flat prior distributions were assigned to α_{kt} and normal prior distributions with zero mean and large variance were assigned to parameters β_{kt} .

Posterior distributions for the parameters of interest were simulated by using the Markov Chain Monte Carlo (MCMC)

method in the OpenBUGS software^{7,8}. The MCMC procedure was run for 60,000 iterations after a burn-in of 6,000 iterations. The 95% credible intervals (95% CI) were obtained by taking the mean and 2.5% and 97.5% quantiles of the MCMC posterior sample of the respective parameters. Credible intervals are the Bayesian analogue of frequentist confidence intervals. For the fit of Model 2, whenever the limits of CI for parameter β_{kt} do not include zero, there is a significant effect of covariate X on the AIDS incidence for individuals of gender k at time t .

This research was approved by the Research Ethics Committee of Hospital das Clínicas, Ribeirão Preto Medical School, University of São Paulo (protocol number 565.914).

Figure 1 describes the spatial distribution of HDI and its three components. The highest scores are concentrated in the central region, showing areas of greater wealth, decreasing as they move away from the center toward the peripheries.

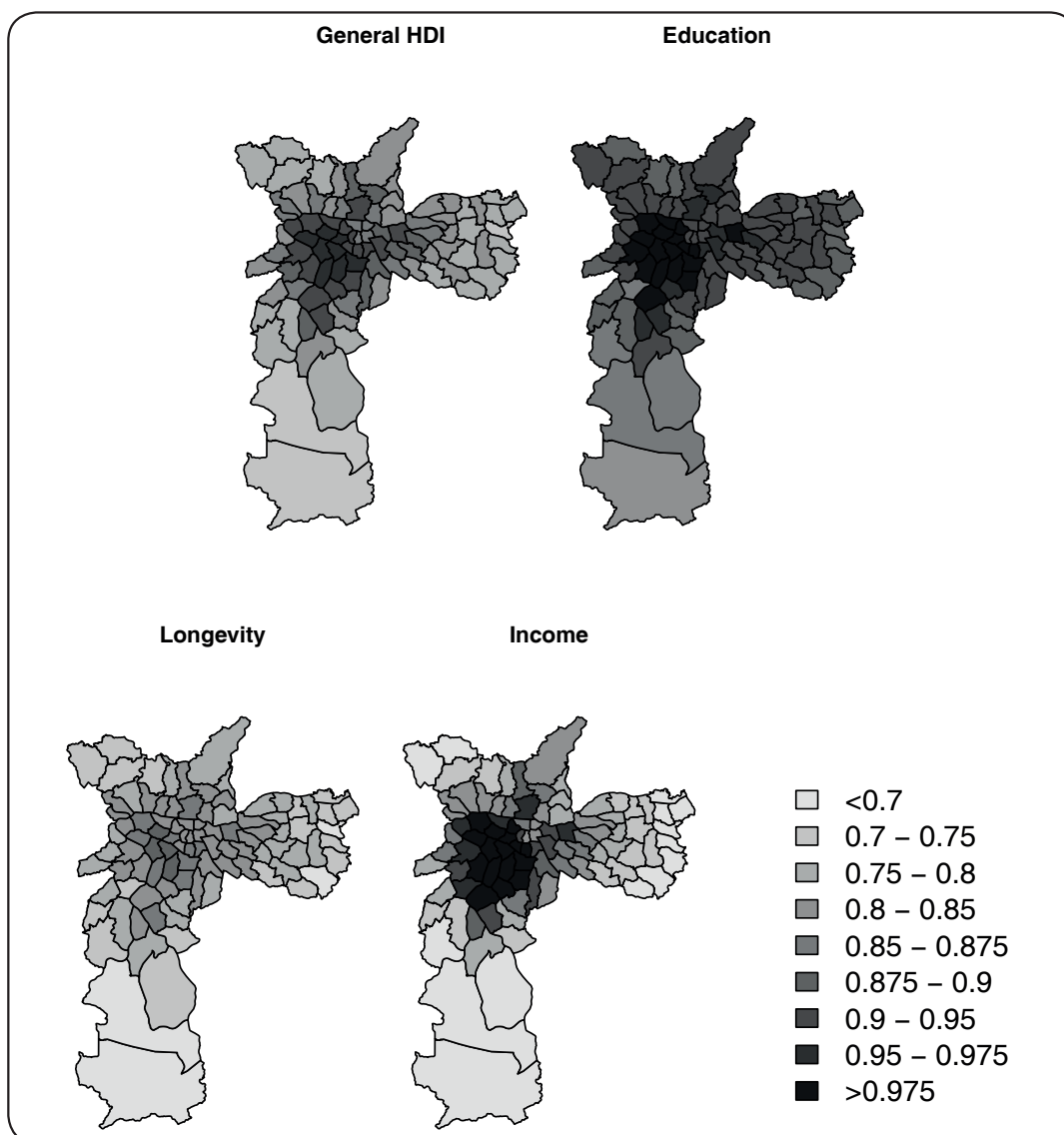


FIGURE 1: Thematic maps describing the spatial distribution of (a) general human development index (HDI) and its three components: (b) education, (c) life expectancy, and (d) income (year 2000).

The fit of Model 1 allowed for the smoothing of crude rates regarding gender, according to the spatiotemporal pattern. **Figure 2** indicates the spatial distribution of these smoothed rates of AIDS incidences for men and women, considering the years 2000, 2008, 2013, and 2016. Maps for the other years are not shown because of the large quantity of data. Among men, the central ADs tend to have highest incidence rates per 100,000 inhabitants; however, these rates tend to decline over the years. Considering the male population, in 2000, São Paulo had a median smoothed AIDS incidence of 37.98 cases per 100,000 inhabitants among the 96 ADs (interquartile range

[IQR] 30.63 to 55.26). This incidence decreased to 29.26 (IQR 23.59 to 42.56) and 8.84 (IQR 7.13 to 12.86) in 2008 and 2016, respectively.

The maps also indicate that, among women, the highest AIDS incidence rates were found in some central areas of the municipality at the beginning of the study period; however, the maps tend to indicate a more heterogeneous spatial distribution of the incidence rates as we approach the end of this period. In 2000, São Paulo's ADs had a median smoothed incidence of 17.58 cases per 100,000 inhabitants among women (interquartile range [IQR] 14.47 to 25.35). This incidence decreased to 13.27

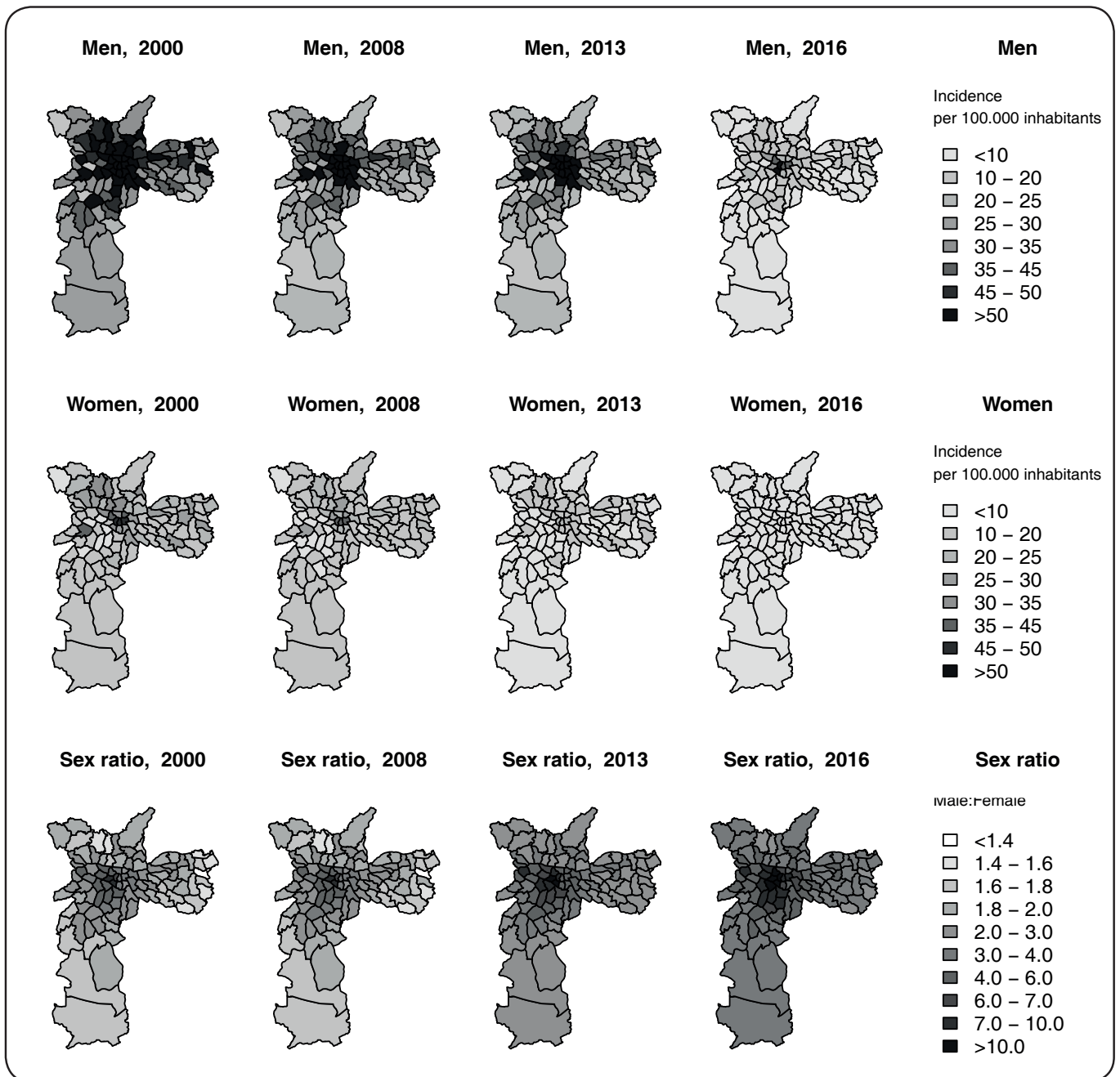


FIGURE 2: Spatial distribution of the smoothed AIDS incidence rates among men (first line) and women (second line), obtained from the spatiotemporal model (without covariates). Spatial distribution of the male to female AIDS incidence ratio (third line), São Paulo, from 2000 to 2016.

(IQR 10.93 to 19.14) and 2.14 (IQR 1.76 to 3.09) in 2008 and 2016, respectively.

Figure 2 also indicates maps of the male to female AIDS incidence ratio in São Paulo, also estimated from the fit of Model 1. The maps suggest an increase in this ratio over the study period. In 2000, the median for the male to female incidence ratio was 2.0 (IQR 1.8 to 2.9) similar to 2.1 (IQR 1.8 to 3.0) in 2008. However, in 2013 and 2016 the median increased to 2.9 (IQR 2.5 to 4.1) and 3.9 (IQR 3.4 to 5.5), respectively. In general, the highest male to female incidence ratios were observed in the central ADs. However, at the end of the study period, the maps suggested a more homogeneous spatial distribution of this ratio.

Figure 3 indicates 95% CI for the estimates of parameter β_{kt} in Model 2 regarding the effect of each HDI component on AIDS incidence for each gender and year. Intervals containing zero indicate no evidence of significant effect. A positive association

between HDI and its three components and AIDS incidence (values for β_{kt} higher than zero) was observed among men, considering the initial years of the period. This relationship was not observed at the end of this period. From these results and by comparing the maps shown in **Figures 1 and 2**, we have evidence that in the early 20th century the new AIDS cases among men were more likely to occur in more developed regions of São Paulo; however, this trend began to diminish in the second decade of this century. **Figure 3** suggests a different association pattern between HDI components and AIDS incidence among women. A lack of association is visible at the beginning of the century (CIs for β_{kt} include zero); however, the estimates for the association parameters become negative and significant at the end of this period. These results suggest that, from the second decade of this century, AIDS incidences among women decreased in the more developed regions of the municipality.

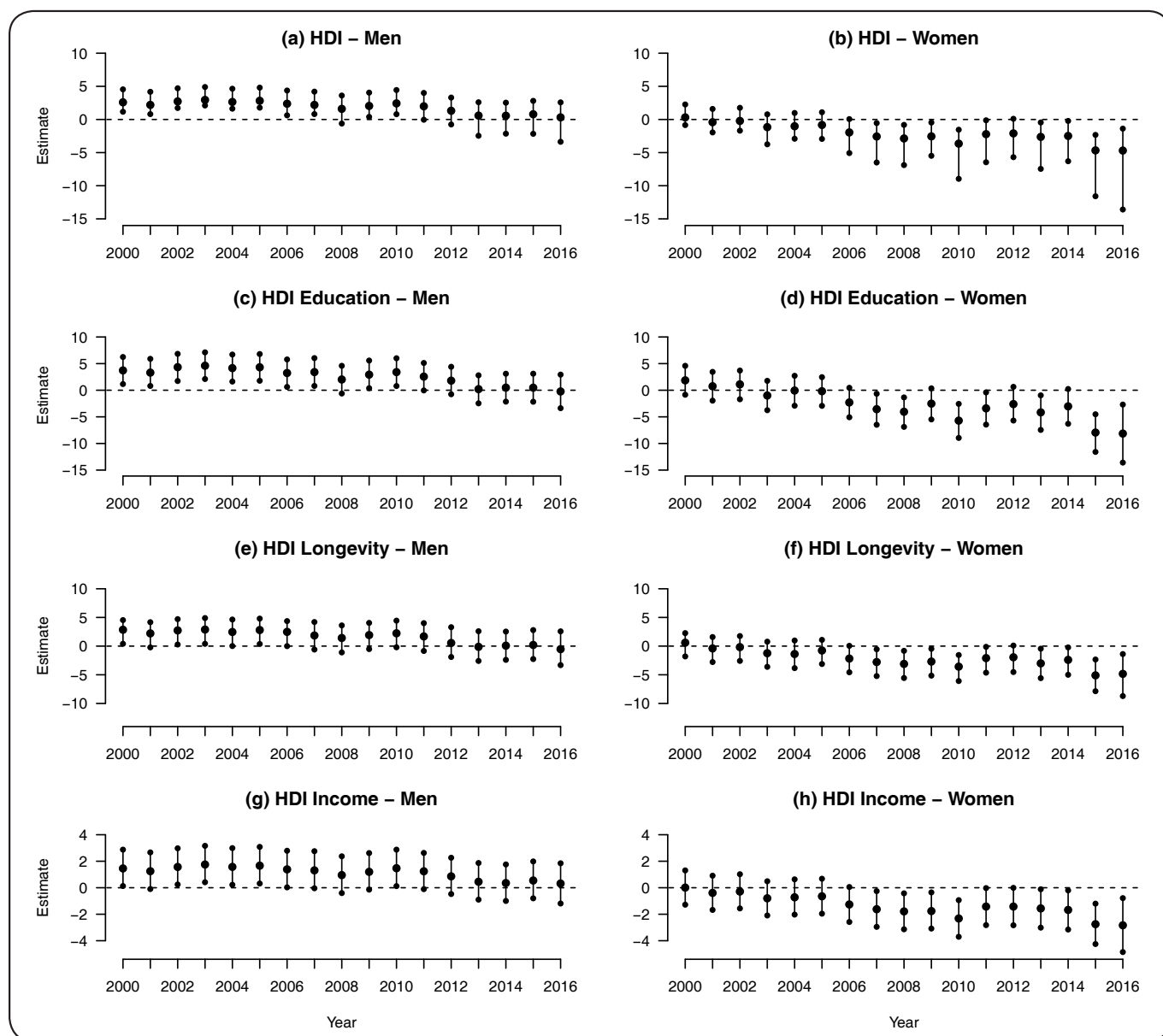


FIGURE 3: Estimates of parameters β_{kt} obtained from Model 2 and their 95% credible intervals, considering each HDI component.

This study proves that the geographical distribution of ADs in São Paulo indicates deep social and economic differences, with central areas being more developed due to the concentration of higher income people with greater purchasing power, whereas lower income people with less purchasing power are concentrated in the peripheral areas. Therefore, our results suggest that in the early 20th century, the more developed ADs indicated higher AIDS incidences among men. However, from the second decade of the century, ADs with lower economic classes indicate higher rates of the disease among women. In part, this phenomenon is already well known across Brazil, mainly in the country's major cities, and is referred to as impoverishment and feminization of the AIDS epidemic. This is translated into a dissemination of the disease among the poor and female population⁹, proving the HIV-carriers' behavioral aspects and changes in the predominantly homosexual pattern of disease transmission between men, which now includes women, resulting in another phenomenon, the so-called heterosexualization of AIDS¹⁰. This phenomenon suggests that women from lower socioeconomic classes are more susceptible to AIDS due to their partner's behavioral aspects, such as unprotected extramarital sex, non-use of condoms during sex with the wife, and use of injectable drugs¹¹. In sum, it is known that the AIDS history in Brazil indicates that the disease had initially reached upper socioeconomic groups and homosexual individuals; however, now it is reaching people from all socioeconomic classes regardless of their sexual behavior².

This study was performed in a metropolis with great socioeconomic diversity, harboring people from various parts of the world whose behaviors and cultural habits are typical of those observed in other major cities worldwide. In this way, the distribution pattern of the disease does not differ from those reported by other studies performed in other metropolises, including some of China's and North-America's most populated cities^{12,13}. The results for these similarities are no secret since they are undoubtedly due to the poor life conditions such as low income and education level, urban agglomeration, promiscuity, and other risk behaviors, among other factors, all being currently observed in the peripheral regions of major cities¹⁴. However, similar events have also been observed in smaller cities and rural towns, pointing to the emergence of other phenomena, namely, interiorization and ruralization of the disease¹⁵.

Potential limitations of this study are related to information type and study design. Although our data have come from health information systems, they do not precisely describe the actual situation as there are issues regarding how the AIDS cases are notified and related recorded information, despite the mandatory notification of the disease. Because this is an ecological study, it is not possible to generalize the results to an individual information level. The use of synthetic indicators also restricts any study extrapolation given the methodological and conceptual limitations, including inadequate use of indicators when confronted with health information.

Our results are useful to support the planning of public health policies and actions aimed at controlling the incidences and transmission of AIDS in certain areas on the basis of gender

and risk populations diversification in São Paulo, Brazil. We also emphasize the need for personalizing access to healthcare services by administrative district and gender in order to propose a healthcare strategy for men and women in each area by establishing local support teams with particular characteristics, as demonstrated in this study.

Acknowledgments: We would like to thank *Fundação de Amparo à Pesquisa do Estado de São Paulo* (FAPESP) for the financial support. The third author is supported by a grant from *Conselho Nacional de Desenvolvimento Científico e Tecnológico*.

Conflict of interest: The authors declare that there is no conflict of interest.

Financial support: This study was supported by the *Fundação de Amparo à Pesquisa do Estado de São Paulo* (FAPESP) under grant #12/16717-9, and *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq), process 305942/2012-3).

REFERENCES

- Alves AT, Nobre FF, Waller LA. Exploring spatial patterns in the associations between local AIDS incidence and socioeconomic and demographic variables in the state of Rio de Janeiro, Brazil. *Spat Spatiotemporal Epidemiol*. 2016;17:85-93.
- Barcellos C, Acosta LM, Lisboa EP, Brito MR, Flores R. Estimate of HIV prevalence in pregnant women by means of spatial analysis in Southern Brazil. *Rev Saude Publica*. 2006; 40(5):928-30.
- Grangeiro A, Escuder MM, Castilho EA. The AIDS epidemic in Brazil and differences according to geographic region and health services supply. *Cad Saude Publica*. 2010; 26(12):2355-67.
- Silva-Lizzi EA, Nunes AA, Martinez EZ. Spatiotemporal analysis of AIDS incidence among adults in Brazil. *Curr HIV Res*. 2016;14(6):466-475.
- Lee D. A comparison of conditional autoregressive models used in Bayesian disease mapping. *Spat Spatiotemporal Epidemiol*. 2011;2(2):79-89.
- Branscum AJ, Perez AM, Johnson WO, Thurmond MC. Bayesian spatiotemporal analysis of foot-and-mouth disease data from the Republic of Turkey. *Epidemiol Infect*. 2008;136(6):833-42.
- Smith AF, Roberts GO. Bayesian computation via the Gibbs sampler and related Markov chain Monte Carlo methods. *J R Stat Soc Series B Stat Methodol*. 1993;55(1):3-23.
- Lunn DJ, Thomas A, Best N, Spiegelhalter D. WinBUGS - A Bayesian modelling framework: concepts, structure, and extensibility. *Stat Comput*. 2000;10(4):325-37.
- Fonseca MG, Bastos FI. Twenty-five years of the AIDS epidemic in Brazil: principal epidemiological findings, 1980-2005. *Cad Saude Publica*. 2007;23(Suppl 3):S333-44.
- Maia C, Guilhem D, Freitas D. Vulnerability to HIV/AIDS in married heterosexual people or people in a common-law marriage. *Rev Saude Publica*. 2008;42(2):242-8.
- Gavin L, Galavotti C, Dube H, McNaghten AD, Murwirwa M, Khan R, Louis MS. Factor associated with HIV infection in adolescent females in Zimbabwe. *J Adolesc Health* 2006; 39(4): 596.e11-596.e18.
- Wang Y, Yang Y, Shi X, Mao S, Shi N, Hui X. The spatial distribution pattern of human immunodeficiency virus/acquired immune deficiency syndrome in China. *Geospat Health*. 2016;11(2):414.

13. Song W, Mulatu MS, Rorie M, Zhang H, Gilford JW. HIV Testing and Positivity Patterns of Partners of HIV-Diagnosed People in Partner Services Programs, United States, 2013-2014. *Public Health Rep.* 2017;132(4):455-62.
14. Burch LS, Smith CJ, Anderson J, Sherr L, Rodger AJ, O'Connell R, *et al.* Socioeconomic status and treatment outcomes for individuals with HIV on antiretroviral treatment in the UK: cross-sectional and longitudinal analyses. *Lancet Public Health* 2016; 1(1):e26-e36.
15. Carvalho BC, Cardoso LP, Damasceno S, Stefani MM. Moderate prevalence of transmitted drug resistance and interiorization of HIV type 1 subtype C in the inland North State of Tocantins, Brazil. *AIDS Res Hum Retroviruses.* 2011;27(10):1081-7.

