Artículo / Investigación
Article / Research

Environmental and demographic determinants of dengue incidence in Brazil

Determinantes ambientales y demográficos asociados con la incidencia del dengue en Brasil

Igor Cavallini Johansen, Roberto Luiz do Carmo, Luciana Correia Alves and Maria do Carmo Dias Bueno

Received 23th November 2015 / Sent for Modification 16th August 2017 / Accepted 25th January 2018

IC: Sociologist. MA and Ph. D. Demography. Post-doc at University of São Paulo (USP). São Paulo, Brazil. *igorcavallini@usp.br*
RC: Sociologist. MA and Ph. D. Demography. Professor at University of Campinas (UNICAMP) and researcher at Population Studies Center (NEPO/UNICAMP). Campinas, Brazil. *roberto@nepo.unicamp.br*
LA: Physiotherapist. MA Demography. Ph. D. in Public Health. Professor at University of Campinas (UNICAMP) and researcher at Population Studies Center (NEPO/UNICAMP). Campinas, Brazil. *luciana@nepo.unicamp.br*
MB: Civil Engineer. M. Sc. Civil Engineering, M. Sc. in Geomatics and Ph. D. Demography. Technician in Geographical and Statistical Information at the Brazilian Institute of Geography and Statistics (IBGE). Rio de Janeiro, Brazil. *bueno.mariadocarmo@gmail.com*

ABSTRACT

Objective To analyze the spatial distribution of dengue fever cases within an urban area of the São Paulo State, southeast Brazil.
Methods Based on a methodology created by the authors, it was possible to organize the Brazilian Census data of 2010 into a regular grid of 250x250 meters each cell. This cell was the unit of analysis. Then, the 1 688 residential addresses of autochthonous dengue cases reported in 2013 in Caraguatatuba city were geocoded to calculate the incidence rate by cell. The dependent variable was the dengue incidence rate and the independent variables were classified into two types: environmental and sociodemographic. Finally, a Zero-Inflated Negative Binomial Regression was performed using the software R.
Results The statistical analysis showed an association between dengue incidence rate and the environmental variable "proximity to strategic points (junk yards, tire repair shops and deposits of recyclable materials)." Dengue was also associated to the sociodemographic variables "proportion of households with per capita income up to 3 minimum wages", "proportion of nonwhite people" and "proportion of not owned households".
Conclusion Dengue is associated to several factors related to its epidemic outbreak. In this complex context, results suggest that this infectious disease is socially conditioned, since it is more likely to reach population groups with specific characteristics, notably those with low socioeconomic status.

Key Words: Dengue; environmental health; population dynamics; regression analysis; Brazil *(source: MeSH, NLM).*

RESUMEN

Objetivo Analizar la distribución espacial de los casos de dengue dentro de un área urbana en el estado de Sao Paulo, sudeste de Brasil.
Métodos Basados en una metodología creada por los autores, se organizaron los datos del censo brasileño de 2010 en una malla regular de 250x250 metros cada célula. Esta célula fue la unidad de análisis. En seguida, fueran gecodificadas todas las 1 688 residencias de los casos de dengue registrados en 2013 en la ciudad de Caraguatatuba para calcular la tasa de incidencia por célula. La variable dependiente fue la tasa de incidencia del dengue y las variables independientes fueron clasificadas en dos tipos: ambientales y sociodemográficas. Finalmente se realizó una Regresión Binomial Negativa Inflada con Ceros utilizando el software R.
Resultados El análisis estadístico mostró una asociación entre la tasa de incidencia del dengue y la variable ambiental proximidad de puntos estratégicos (depósitos de chatarra, talleres de reparación de neumáticos y depósitos de materiales reciclables). El dengue también se asoció a las variables sociodemográficas proporción de hogares con ingreso per cápita de hasta 3 salarios mínimos, proporción de personas no blancas y de hogares que no sean propiedad.

DOI: https://doi.org/10.15446/rsap.V20n3.54315

Conclusión Se concluyó que el dengue tiene un conjunto múltiple de factores relacionados con la aparición de sus epidemias. En el contexto de esta complejidad, los resultados sugieren que esta enfermedad infecciosa está condicionada socialmente, ya que es más probable que llegue a grupos de población con características específicas, especialmente aquellos con un nivel socioeconómico bajo.

Palabras Clave: Dengue; salud ambiental; dinámica poblacional; análisis de regresión; Brasil *(fuente: DeCS; BIREME).*

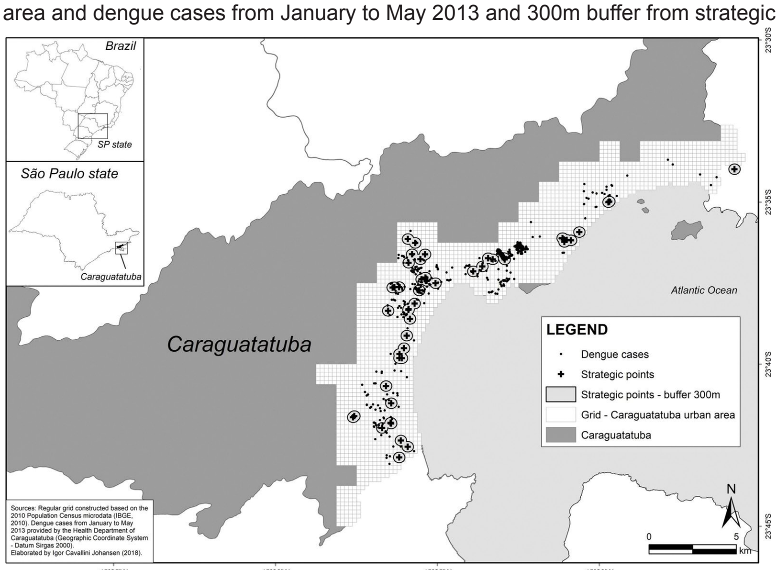
Dengue is an infectious disease typical of urban areas. It is caused by an arbovirus distinguished by four distinct serotypes: DEN-1, DEN-2, DEN-3 and DEN-4. Estimates are that about fifty million dengue infections occur each year in more than 100 countries. About two and a half billion people live in areas where dengue is endemic, mainly in Asia, Africa and South America. (1-3)

Partly due to the size of its population, but also because of favorable climatic conditions, Brazil has the highest number of dengue cases in South America. In this country, dengue cases have increased substantially over the years: 2 000 cases in 1992, 508 000 in 1998, 692 000 in 2002, more than 1 million in 2010, and more than 1.4 million in 2013(4). The increasing exchange of goods and greater velocity of the transportation; the growing spatial mobility of the population; the expansion of urban areas without sufficient planning and poor water supply that leads to store water at homes; and the inadequate collection and disposal of garbage are among the most relevant conditions involved in dengue transmission. Some of these factors are closely related to the proliferation of the mosquito vector of this disease, Aedes aegypti (5-8).

An intense process of urbanization occurred in Brazil especially during the second half of twentieth century. In 1950, about 36% of the population (18.7 million people) lived in areas defined as urban. In 2010, the urban population reached 84% (160.9 million people)(9). So an increase of 142 million people took place in Brazilian cities over 60 years. On the one hand, these numbers give us a glimpse of the scale of urban growth in Brazil, and on the other, it helps to understand the difficulties inherent in this process, especially considering the low intervention of Brazilian policy-makers in terms of planning and guidance on this process.

The municipality of Caraguatatuba is located in the northern coast of the State of São Paulo, Brazil (Figure 1), and was chosen as the study area for a number of reasons: 1) this municipality is highly urbanized: according to the most recent Population Census, in 2010 more than 95% of Caraguatatuba population was living in the urban area (9); 2) it is an important tourist site and, consequently, a space of high circulation of people, making this city highly exposed to the entrance of new serotypes of the dengue virus (10); 3) Caraguatatuba has systematically had dengue epidemic outbreaks: in 2002, 2004, 2007, 2010, 2011 and, more recently, 2013, the year on which this analysis is (11); and 4) this city has strong socioeconomic inequalities; consequently it is similar to many other Brazilian and Latin American urban centers in this sense (Figure 1).

Figure 1. Caraguatatuba municipality, in the State of São Paulo, Brazil. Regular grid of the urban area and dengue cases from January to May 2013 and 300m buffer from strategic points



Notes: a The cells correspond only to the urban area. Because dengue is primarily an urban disease, only this area was examined. b The considerable portion of the territorial municipality not classified as urban comprises mainly a vegetation-covered area of the Serra do Mar State Park.

Caraguatatuba had a population of 109 678 inhabitants in 2013. (12) In the same year, the municipality reported 1 688 autochthonous dengue cases (11), with an incidence rate of 1 359 cases per 100 000 inhabitants, which is far beyond the epidemic threshold: 300 cases per 100 000 inhabitants. It should be noted that only autochthonous cases were selected for this study, as they are related to transmission within the municipality and the infected person was a resident.

Only dengue cases in residents were considered because this study aimed to compare the characteristics of the population and its place of living to dengue cases distribution. Given that dengue is a disease mainly related to the urban environment, this study was centered on the urban area of Caraguatatuba. The Caraguatatuba Health Department conducted virus isolation tests that showed that DEN-1 was the circulating dengue serotype in 2013.

The aim of this study was to investigate the spatial distribution of dengue cases in the intra-urban scale, looking for its social and environmental conditioning factors. This works focuses on the characteristics of the population and the urban environment, whose historical process of expansion and consolidation may constitute favorable conditions for the proliferation of the mosquito *Aedes aegypti*. This article analyzes the case of the city of Caraguatatuba, located in the State of São Paulo, Brazil, in 2013.

METHODS

Data sources

Residential addresses of patients infected with dengue fever virus and the location of strategic points for dengue control —junk yards, tire repair shops and deposits of recyclable materials (13) — were obtained from the Health Department of Caraguatatuba. These addresses were geocoded according to their location in the city using the software ESRI® ArcMap™ 10.0. Given the importance of the strategic points to the spread of dengue vectors, a buffer of 300 meters was drawn around each of them, looking for their area of influence, as well as their proximity to dengue cases (Figure 1).

The 300 meters buffer corresponds to the flight radius of the mosquito *Aedes aegypti* (14,15). Strategic points are considered as important breeding sites for the dengue vector, from where the mosquitoes could reach the resident population living up to 300 meters of distance.

The socioeconomic data of the population and the urban environmental characteristics were obtained from the Population Census of 2010. (9) A new way to organize this data was proposed in order to increase the accuracy and to capture with more fidelity the differences of population composition within our study area. For this purpose, a special permission was requested from the Brazilian Institute of Geography and Statistics (IBGE) to access the microdata of the Population Census. This was possible only in the administrative center of IBGE in the city of Rio de Janeiro.

Then, microdata were aggregated into units of a regular grid, each one measuring about 0.0625 km^2 or 250x250m (16), covering the area classified by IBGE as urban (Figure 1). The regular grid used in this study is a form of representation of spatial information; data aggregation certifies that no one can be identified, ensuring the confidentiality guaranteed by IBGE. The structure of this regular grid has already been tested in analyses concerning other subjects and areas (17-19).

The underlying assumption of using the Census data of 2010 and the dengue cases of 2013 is that, in this period, changes in composition and structure of the population and sanitation infrastructure were not significant.

Variables

Dengue cases within each unit of analysis were counted by the software ESRI® ArcMap™ 10.0 and were included in the database together with the Census information. The variable "dengue incidence rate" was estimated from the quotient between dengue cases and number of residents in each cell.

In order to understand the change in the dengue incidence rate in the city of Caraguatatuba (dependent variable), 7 independent variables were created: 4 concerning the environment and 3 the sociodemographic status (Chart 1).

Statistical analysis

A Zero-Inflated Negative Binomial Regression (ZINB) was performed using the software R, version 3.12.0. Exploratory analysis of the data showed that ZINB was the most appropriate model. This finding was corroborated by the literature review about the specificities of this regression type. (20-22) The modeling strategy was based on various simple models of Zero-Inflated Negative Binomial Regressions. The model results were presented as a ratio of the incidence rate, taking 95% as the confidence interval.

RESULTS

Table 1 presents the results of the simple models of Zero-Inflated Negative Binomial Regressions. The results of the models show that environmental conditions of sanitation (waterinad: proportion of households with inadequate water, sewinad: proportion of households with inadequate sewage and wasteinad: proportion of households with inadequate waste collection) did not reach statistica-

Chart 1. Independent variables used for statistical analysis

Name	Category	Description	Type
waterinad	Environmental	Proportion of households with inadequate water (well or spring in the property + well or spring out the property + water truck + rainwater stored in tanks + rainwater stored in another way + river, ponds, lakes, streams + other).	Numerical
sewinad	Environmental	Proportion of households with inadequate sewage (rudimentary sewage + ditch + river, lake, sea + other).	Numerical
wasteinad	Environmental	Proportion of households with inadequate garbage collection (burned in the property + buried in the property + thrown into a vacant lot or street + thrown into river, lake, sea + another destination).	Numerical
proximity	Environmental	Proximity of up to 300 meters to strategic points (junk yards, tire repair shops and deposits of recyclable materials). 1=yes, 0=no	Categorical
up3mw	Sociodemographic	Proportion of households with per capita income of up to 3 minimum wages.	Numerical
nwhite	Sociodemographic	Proportion of non-white people.	Numerical
notowned	Sociodemographic	Proportion of not owned households (rented + given in by employer + given in by another way + other condition).	Numerical

Note: The dependent variable is the dengue incidence rate

lly significant relationships at 5%. On the other hand, the statistically significant variables were proximity to strategic points (proximity), proportion of households with per capita income of up to 3 minimum wages (up3mw), proportion of non-white people (nwhite) and proportion of not owned households (notowned).

Table 1. Ratio of the incidence rate of the zero-inflated negative binomial regression models for dengue. Campinas, São Paulo, Brazil, January to May 2013

Variables	Ratio of the incidence rate	p-value
waterinad	0.13	0.057
sewinad	1.28	0.658
wasteinad	0.00	0.059
proximity	1.67	0.047
up3mw	71.71	0.000
nwhite	4.36	0.041
notowned	0.08	0.000

Source: Own elaboration based on software R outputs

Living in an area up to 300 meters around a strategic point increased by 67% the dengue incidence rate. Furthermore, the 1% increase in the proportion of households with per capita income of up to 3 minimum wages corresponded to an increase of 71 times the dengue incidence rate. Additionally, the increase of 1% in the proportion of non-white people contributed to boost over 4 times that rate. On the other hand, as protection factor, a 1% increase in the proportion of not owned households reduced by 92% the dengue incidence rate in the study area.

DISCUSSION

The regular grid used in this investigation increased the spatial resolution of sociodemographic data considering that the census tract is the smallest unit of analysis in which the data of the Population Census are traditionally available. Census tracts are irregular in size and can cover different areas in terms of environmental characteristics and composition of the population. In this sense, the aggregation of microdata and the representation in terms of a regular grid provided to this study a resolution level never used before in a research on dengue fever in the country. This methodology also facilitated the overlapping of different background information: health data and sociodemographic and environmental information.

The literature has found robust results that support the hypothesis of the relationship between sanitation and dengue (23-26). In this study, however, environmental sanitation variables were not statistically significant. This phenomenon may be explained by the coverage of sanitation services in the urban area of Caraguatatuba. Water supply by general network and garbage collection was found in over 98% of the households. Sewage collection, on the other hand, reached about 57% of urban households in the municipality. Consequently, water supply and garbage collection, whose gaps in the service present higher potential risks to create breeding sites for *Aedes aegypti*, were virtually universalized. Thus, sanitation in the study area apparently did not comprise an element that could trigger massive dengue epidemics.

Among the statistically significant variables of the models, the crucial importance of sites such as junk yards, tire repair shops and deposits of recyclable materials was demonstrated. Therefore, living within up to 300 meters of these sites increased by 67% the dengue incidence rate in that locality. This result reinforces the importance of these strategic points for controlling *Aedes aegypti*, as reported by other studies (27-29).

The variable proportion of households with per capita income of up to 3 minimum wages was also statistically significant in the analysis. This finding is consistent with results previously observed in other studies. (30-32) However, it is still an open debate, since other investigations have found associations between high income and dengue fever, depending on the scale of the analysis, as stated by the literature review performed by Flauzino, Souza-Santos & Oliveira (33).

In addition, the increase in the proportion of non-white people contributed to the rise of the dengue incidence rate by more than four times. In Latin America as a whole and particularly in Brazil, the skin color of the population and the socioeconomic status, as well as the epidemiological profile, are still closely associated. There is scarce literature that analyzes skin color or ethnicity in relation to dengue cases, and results are not conclusive as they depend on the selected area for the study and the methodology adopted (34,35).

Finally, a statistically significant relationship between dengue incidence rate and type of household occupation was found in the case of not owned households, a fact that has no precedents in the literature review.

This leads to hypothesize that residents of not owned households may have a weaker feeling of belonging in relation to the property, which could converge in lower levels of care about the house and its surroundings. Negligence towards the domestic space is a major concern of policy makers to successfully achieve dengue control.

However, the scenario can be slightly different in a touristic city like Caraguatatuba, where a massive number of households of occasional use can be observed. In 2010, according to the Population Census data, 43.2% of private households in Caraguatatuba were for occasional use. In this context, the ownership of the property does not necessarily mean greater attention to breeding sites of the dengue vector. This happens because owners often let their properties closed during the off-season, barely visiting them for short periods of time. In contrast, rented houses, although not owned by the resident, regularly have people on site that can check for stagnant water places and also allow the entry of epidemiological surveillance agents to carry out the chemical and mechanical control of *Aedes aegypti*. Therefore, in Caraguatatuba, it makes sense that not owned households are a protective factor for dengue cases. This point, however, should be further investigated in non-touristic areas.

It is important to remember that the contrasting associations found in studies of dengue outbreaks and socioeconomic and environmental conditions may be related to the level of data aggregation (such as regular grid, census tracts, neighborhoods, districts or municipalities etc.). In other words, different spatial units of analysis may produce divergent results. Given its small size and flexibility, the regular grid presented in this study can be aggregated in any desired shape. Consequently, its use as basis for testing new units of analysis, evaluating and comparing results in future studies is promising.

Furthermore, the findings from this study should be analyzed considering that this disease, taking into account its multifactorial nature, presents a set of elements that, together, are responsible for triggering the occurrence of an outbreak. In addition to the characteristics of the population and their households, which have consequences specifically on the production of breeding sites for the vector, the immunity acquired by the population to each of the circulating virus serotypes should also be considered. For the purposes of this investigation, viral dynamics could not be encompassed, and this is one of its limitations.

Another limitation is the small period of time used for this analysis. Although it is common to select some months or one year to study dengue fever epidemics (7,29,36), the purpose of future investigations should be to analyze this health problem for a longer period of time.

The goal of this analysis was to investigate the spatial distribution of dengue cases in the intra-urban level and verify to what extent this distribution was related to the socioeconomic and environmental conditions of the resident population. To this end, this study analyzed the case of the city of Caraguatatuba, located in the State of São Paulo, Brazil, in 2013.

In conclusion, socio-spatial inequalities likely conditioned dengue cases. There are two main reasons to state that: firstly, cases were not evenly distributed inside the city studied (Figure 1) and, secondly, the regions within the urban area presenting higher dengue incidence rates comprised the underprivileged population in terms of socio-economic and environmental conditions, such as living close to strategic points and having lower income between the analyzed groups (Table 1).

The regular grid of 250x250 m allowed developing a very detailed study at the intra-municipal level, bringing also the difficulty of the excess of zeros, which was circumvented by using a model designed for this specific type of data.

Beyond the methodological innovation proposed and tested in this study, this investigation, by providing information for the development of group-focused public polices, is expected to make a contribution to develop more precise, sustainable and cost-effective dengue control interventions •

Conflict of interest: None.

Funding: Special thanks to the National Council for Scientific and Technological Development (CNPq-Brazil), for providing the financial support for this research.

Acknowledgements: We would like to thank the Caraguatatuba Health Department for providing the dengue cases and strategic points addresses. We also express our gratitude to the

IBGE for its support with the access to the Brazilian Population Census microdata.

REFERENCES

1. World Health Organization (WHO). Report of the Scientific Working Group meeting on Dengue. Special Programme for Research & Training in Tropical Diseases (TDR). Geneva, Switzerland: WHO; 2006.
2. World Health Organization (WHO). Dengue guidelines for diagnosis, treatment, prevention and control. New edition. Geneva, Switzerland: WHO; 2009.
3. Dengue fever climbs the social ladder. Editorial. Nature 2007; 448: 734-735.
4. Brazil. Health Ministry. Dengue Cases. Brazil, Large Regions, States – 1990 to 2013. Dada updated on July 2014. Disponible en: http://goo.gl/pmAIOd. Consultado en febrero de 2015.
5. Donalisio MR. O dengue no espaço habitado. São Paulo: Hucitec: Funcraft; 1999.
6. Tauil PL. Urbanização e ecologia do dengue. Cad. Saúde Pública. 2001; 17: 99-102.
7. Hayes JM, García-Rivera E, Flores-Reyna R, Suárez-Rangel G, Rodríguez-Mata T, Coto-Portillo R, et al. Risk factors for infection during a severe dengue outbreak in El Salvador in 2000. Am J Trop Med Hyg. 2003; 69(6): 629-633.
8. Rodríguez G, De La Hoz R. Dengue and dengue and vector behaviour in Cáqueza, Colombia, 2004. Rev. de Salud Pública (Bogotá). 2005; 7(1): 1-15.
9. Brazilian Institute of Geography and Statistics (IBGE). Population Census 1950 and 2010. Disponible en: http://goo.gl/HhVCGe. Consultado en noviembre de 2015.
10. Johansen IC. Urbanização e saúde da população: o caso da dengue em Caraguatatuba (SP) [Dissertation]. Campinas: Institute of Philosophy and Human Sciences, State University of Campinas, Brazil; 2014.
11. Caraguatatuba Health Department. Contingency Plan against Dengue. Reviewed by Ceci Oliveira Penteado, Cláudia Cristina Garcia Rocha Pires and Ricardo Fernandes de Sousa; 2013.
12. Brazilian Institute of Geography and Statistics (IBGE). Population estimates 2013. Disponible en: https://goo.gl/AfD3iD. Consultado en junio de 2018.
13. Brazil. Health Ministry. Health Surveillance Secretary. Department of Epidemiologic Surveillance. Diretrizes nacionais para prevenção e controle de epidemias de dengue. Brasília: Health Ministry; 2009. Disponible en: http://goo.gl/4nwnuZ. Consultado en marzo de 2015.
14. Barrera R. Estudios geo-espaciales de la ecología y control de los mosquitos vectores y de la transmisión del dengue. In: Arrivillaga JC, Souki ME, Herrera B. editors. Enfoques y temáticas en entomología. Primeira edição. Maracaibo, Venezuela; 2009.
15. Freitas RM. Avaliação de aspectos da capacidade vetorial de fêmeas de *Aedes aegypti* (Diptera: Culicidae) no Rio de Janeiro [Thesis]. Rio de Janeiro: Oswaldo Cruz Foundation (Fiocruz); 2010.
16. Johansen IC, Carmo RL, Bueno MCD. Water, sanitation and health: an intra-urban comparison in the municipality of Caraguatatuba, Brazil. Water Int. 2013; 38(7): 888-901.
17. D'Antona AO, Dagnino RS, Bueno MCD. Geotecnologias e Gestão de Políticas Públicas: uso de dados demográficos. In: Baeninger R., organizer. População e Cidades: Subsídios para o Planejamento e Políticas Sociais. 1ed. Brasília: United Nations Population Fund (UNFPA); 2010. p. 99-115.
18. Bueno MCD, Dagnino RS. População em Unidades de Conservação da Amazônia Legal: estimativas a partir da Contagem Populacional 2007. In: D'Antona AO, Carmo RL, organizers. Dinâmicas demográficas e ambiente. Campinas: NEPO/Unicamp; 2011. p. 85-103.
19. Bueno MCD, D'Antona AO. Utilização de grades regulares para análises espaciais intramunicipais de variáveis demográficas – testes para Limeira – SP, 2010. Proceedings of the XVIII National Meetings of Population Studies; 2012 November 19-23; Águas de Lindóia/SP, Brazil: ABEP.
20. Mullahy J. Specification and testing of some modified count data models. J Econometrics. 1986; 33(3): 341-365.
21. Ridout M, Demétrio CGB, Hinde J. Models for count data with many zeros. Proceedings of the International Biometric Conference; 1998 December; Cape Town.
22. Yau KKW, Wang K, Lee AH. Zero-Inflated Negative Binomial Mixed Regression Modeling of Over-Dispersed Count Data with Extra Zeros. Biom J. 2003; 45(4): 437-452.
23. Gubler DJ. Dengue and Dengue Hemorrhagic Fever. Public Health. 1998; 11(3): 480-496.
24. Andreazzi MAR, Barcellos C, Hacon S. Velhos indicadores para novos problemas: a relação entre saneamento e saúde. Rev Panam Salud Publica. 2007; 22(3): 211-217.
25. Carmo RL. Urbanization, water and health in Brazil: Aspects of dengue fever epidemics. Proceedings of the XXVI International Population Conference; 2009 September 27- October 02. Marrakech: IUSSP.
26. Teixeira MG, Siqueira-Jr JBS, Ferreira GLC, Bricks L, Joint G. Epidemiological trends of dengue disease in Brazil (2000–2010): a systematic literature search and analysis. PLoS Negl Trop Dis. 2013; 7(12): e2520.
27. Bonini RK. Aspectos da infestação por Aedes (Stegomyia) aegypti e da transmissão de dengue no município de São Paulo [Thesis]. São Paulo: Public Health Faculty, University of São Paulo; 2004.
28. Barbosa GL, Holcman MM, Pereira M, Gomes AHA, Wanderley DMV. Indicadores de infestação larvária e influência do porte populacional na transmissão de dengue no estado de São Paulo, Brasil: um estudo ecológico no período de 2007-2008. Epidemiol. Serv. Saúde. 2012; 21(2): 195-204.
29. Mayo RC, Oliveira MADP, Costa MAF, Alves MJCP, Leite OF, Rangel O, et al. Efetividade das ações de vigilância e controle do *Aedes aegypti* nos pontos estratégicos do município de Mococa, SP-2011. Bol. Epidemiol. Paul. 2013; 10(109): 04-13.
30. Varela SMF, Mateo MM. Estudio ecológico de la fiebre del dengue y el dengue hemorrágico en el municipio de Girardot-Colombia [Thesis]. Barcelona: Universitat Autònoma de Barcelona; 2003.
31. Siqueira JB, Martelli CM, Maciel IJ, Oliveira RM, Ribeiro MG, Amorim FP, et al. Household survey of dengue infection in central Brazil: spatial point pattern analysis and risk factors assessment. Am J Trop Med Hyg. 2004; 71(5): 646-651.
32. Cunha MCM, Caiaffa WT, Oliveira CL, Kroon EG, Pessanha JEM, Lima JA, et al. Fatores associados à infecção pelo vírus do dengue no Município de Belo Horizonte, Estado de Minas Gerais, Brasil: características individuais e diferenças intra-urbanas. Epidemiol. Serv. Saúde. 2008; 17(3): 217-230.
33. Flauzino RF, Souza-Santos R, Oliveira RM. Dengue, geoprocessamento e indicadores socioeconômicos e ambientais: um estudo de revisão. Rev Panam Salud Publica. 2009; 25(5): 456–461.
34. Blanton RE, Silva LC, Morato VG, Parrado AR, Dias JP, Melo PRS, et al. Genetic ancestry and income are associated with dengue hemorrhagic fever in a highly admixed population. Eur J Hum Genet. 2008; 16(6): 762-765.
35. Figueiredo MA, Rodrigues LC, Barreto ML, Lima JWO, Costa MCN, Morato V, et al. Allergies and diabetes as risk factors for dengue hemorrhagic fever: results of a case control study. PLoS Negl Trop Dis. 2010; 4(6): e699.
36. Costa JV, Donalisio MR, Silveira LVA. Spatial distribution of dengue incidence and socio-environmental conditions in Campinas, São Paulo State, Brazil, 2007. Cad. Saúde Pública. 2013; 29(8): 1522-1532.