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Original Paper

Dengue Incidence and Climatic Factors

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Abstract

Introduction: *This study was carried out to analyze the temporal evolution of the incidence of dengue in Araraquara-SP, Brazil, from 2012 to 2016, correlating the incidence with temperature and pluviometry.*

Methods: *It was a cross-sectional design. The monthly number of cases from 2012 to 2016 was collected in the datafile of the Special Health Service of Araraquara-SESA of USP. Climatic variables related to temperature and rainfall were obtained from the websites of Agritempo and Department of Water and Electric Power, respectively. Statistical planning included incidence rates, and the tendency from 2012 to 2016, and it was studied the correlation between the number of dengue cases and each one of the climatic variables, considering the time-lag concept.*

Results: *The incidence rates were 52.68, 376.52, 737.39, 3,660 and 809.48 per 100,000 inhabitants. Significant correlations were observed between the number of dengue cases and climatic variables after 2-4 months for high temperature and after 1-4 months for rainfall.*

Conclusions: *The city faced an epidemic of dengue in 2015. It was identified the time lag in which hot weather and rain favored the occurrence of new cases: 2 to 4 months later for high temperature, and 1 to 4 months later for rainfall.*

Keywords

Aedes aegypti, Dengue, Epidemiology, Descriptive, Pluviometry, Temperature

1. Introduction

Dengue fever is an arboviral disease caused by viruses consisting of four immunologically serotypes, DENV-1 to 4 (Colombo et al., 2013). It is transmitted to humans through the bites of infected female mosquitoes *Aedes aegypti* and it may affect children and adults of any sex and all ages. Dengue patients progress either in a classic manner with or without warning signs or with complications (WHO, 2016; Abe et al., 2012).

Dengue symptoms may include high fever, headaches, muscle and joint pain, retro-orbital pain, skin rash, nausea and vomiting. There is currently no dengue fever vaccine and thus, it is recommended surveillance of potentially active transmission foci (Escosteguy et al., 2013).

Dengue fever has caused illness in humans for hundreds of years affecting millions of people worldwide every year. While it is of international concern, with global expansion, dengue remains a neglected disease (Oliveira et al., 2009).

The incidence of dengue fever has been increasing in Brazil since 1986. Increased rates were reported in all macroregions in 2015, with the highest ones recorded in the Central West and Southeast regions (122.8 and 73.7 cases per 100,000 people, respectively) from January to February 2015 (Brasil, Ministério da Saúde, 2015). In that same year, a dengue fever epidemic outbreak occurred in the Southeast city of Araraquara, in the state of São Paulo, with 8,296 autochthonous cases reported, and an incidence rate of 3,660 cases per 100,000. Of these, 72.4% occurred in people aged 15 to 59 years, and 53.9% among females (Loffredo et al., 2017).

Social and environmental issues and lack of urban development planning are factors that put people at greater risk of developing dengue fever creating background conditions for vector proliferation (Zambrano & San Martin, 2014). Seasonal climatic conditions are another major factor as increases in temperature and humidity may increase the number of mosquito breeding sites and favor dengue vector proliferation (Depradine & Lovell, 2004). In many areas of the Brazilian territory dengue fever cases have been associated with high rainfall and temperature seasonal variation as these conditions contribute to an increase in the number of mosquito breeding sites. Cases mostly occur during the months with higher temperatures and rainfall when climatic conditions are more favorable for vector development (Viana & Ignotti, 2013; Ribeiro et al., 2006).

Seasonal climatic variations do not negatively affect the *Aedes aegypti* cycle, and eggs are viable up to 492 days during the dry season, hatching soon after they are exposed to water (Zara et al., 2016). The life cycle of *Aedes* mosquitoes lasts 10 days and has four phases: egg, larva, pupa and adult (Santos, 2017). Effective disease transmission usually occurs 40 days after the beginning of the rainy season: life cycle for 10 days, incubation period for 15 days and proliferation for 15 days. An infected *Aedes* mosquito is capable of transmitting the virus for its lifespan, i.e., 6 to 8 weeks.

A multifactorial strategy is required to fight against dengue. Health authorities should make all efforts to overturn this scenario of increasing incidences through vector control and minimize harmful effects and reduce deaths from dengue fever. Improved epidemiological surveillance actions along with increased social mobilization and better sanitation conditions are necessary.

Araraquara is a city with one of the highest local human development indexes in the state of São Paulo (CHDI of 0.815) (Atlas do Desenvolvimento Humano, 2016) based on its indicators of income, health and education. It has a robust basic sanitation system with high coverage of water supply (99.43%), sewage collection (99.96%) and waste collection (98.89%), with 100% waste water treatment since 2003 (São Paulo, Fundação Seade, 2017).

Despite its robust indicators, the city showed increasing incidence rates of dengue fever from 2013 to 2015 (400, 740 and 3,660 cases per 100,000), possibly due to a lack of ongoing public health actions resulting in an unexpected increase of dengue cases from one year to the next (Loffredo et al., 2017; Loffredo et al., 2018). The Brazilian Unified Health System (SUS) has undertaken emergency response actions at federal, state and municipal levels to tackle the disease only during epidemic outbreaks (Zara et al., 2016). There have been few campaigns for health education, which may explain low involvement of local population in eliminating *Aedes* breeding sites in households and other private spaces. Collective activities for eliminating mosquito breeding sites such as cleaning up households are not undertaken on a routine basis and are carried out only during epidemic outbreaks. Since studies have associated an increase in the number of dengue cases to higher temperatures and rainfall, prevention measures should be initiated earlier in the year during the months of lower temperatures and rainfall (Ribeiro et al., 2006). Several studies have investigated the effects of environmental and climatic conditions on the dynamics of endemic disease outbreaks (Depradine & Lovell, 2004; Ribeiro et al., 2006; Viana & Ignotti, 2013). To examine the role of climatic conditions in the incidence of dengue fever in the city of Araraquara from 2013 to 2015 (10,850 confirmed cases) and increasing annual incidence rates during this period, we conducted a comparative study to assess the correlation between the incidence of dengue and seasonal climatic conditions for the period 2013-2015 and including 2016. The assessment of the potential association between dengue fever and climatic variables could provide input to help determine the best time for epidemiological surveillance as part of a vector control program.

The background of dengue fever shows that it is a disease with classic signs and symptoms including fever, headache, retro-orbital pain, muscle and joint pain and nausea (Escosteguy, 2013). Dengue is a notifiable disease in Brazil, so that, all cases and deaths must be reported within 1 week and 24 hours, respectively (Brasil, Ministério da Saúde, 2016).

Dengue is a major global health concern, and it affects millions of people worldwide. It is estimated that around 50 million dengue cases occur every year, and, in the Americas, dengue outbreaks are believed to be cyclical occurring every three to five years (Teixeira et al., 2009).

Dengue fever has geographically expanded in Brazil, and its rates have been increasing since 1986 (Portal da Saúde, 2016), mostly in the Central West and Southeast regions.

Broad measures are required against dengue including adequate medical management to reduce deaths in individuals with complications and vector control actions to reduce mosquito proliferation in all regions of Brazil. Epidemiological and laboratory surveillance, population education and social involvement are also necessary (Oliveira et al., 2009), raising awareness about how to prevent mosquito proliferation from its early stages and educating people about dengue and its effects on those affected.

Vector control measures consist of ongoing routine measures when there are suspected and/or confirmed cases including health inspections in buildings and disease education and health teams actively work in an integrated manner to reduce the intensity of dengue transmission (Zara et al., 2016). The local population should have an effective participation, as their involvement is key for dengue control. It is thus necessary to know the temporal trends of dengue incidence as well as its main aspects such as occurrence during a specific time of the year because dengue fever is characterized by recurrent cycles consistent with seasonal variations of rainy and dry periods and temperatures. This knowledge will help developing public policies aiming at surveillance that is more effective and control of dengue in the city.

This study was undertaken to verify the temporal evolution of the incidence of dengue in the city of Araraquara-SP, Brazil for the period 2012–2016, and to assess the correlation between incidence and the climatic variables (temperature and rainfall).

2. Method

This was a cross-sectional study conducted with an exploratory and analytical approach. This research was carried out in the city of Araraquara, which is located in the central region of the state of São Paulo (21°47'40 south latitude and 48°10'32" west longitude, 664 meters of altitude), Brazil. The area has 236,072 inhabitants, a population density of 235,2 people/km^2 and average monthly temperature of 23.01 ℃ (Agritempo, 2017) and average rainfall of 133.77 mm (DAEE, 2017).

The monthly number of cases for the period 2012–2016 was collected from two sources: Special Health Service of Araraquara (Universidade de São Paulo, SESA), and the National Mortality Information System-SINAN records (Brasil, Ministério da Saúde, 2015).

Monthly rainfall information was obtained from the Department of Water and Electric Power website (DAEE, 2017). Temperature information was collected from a weather monitoring system database (Agritempo, 2017).

Incidence rates (I) were calculated using population estimates from the Brazilian Institute of Geography and Statistics (IBGE) based on the 2010 Population Census. Araraquara's population was 212,617 people in 2012; 222,036 in 2013; 224,304 in 2014; 226,508 in 2015; and 228,664 in 2016 (IBGE, 2012-2016). It was used a scatter plot to visualize temporal trends in the incidence of dengue fever (per 100,000) for every year during the study period.

It was calculated the Spearman correlation coefficient (rs) between dengue incidence with each one of the climatic variables (temperature and rainfall) at a 5% significance level.

It was applied the time-lag concept, following the recommendations of Depradine and Lovell (2004). This concept allows investigating phenomena emerging from the interaction with a local environment at a specific point in time (time lag) for the occurrence of dengue considering the mosquito's embryonic development, larval hatching and development of immature forms. Thus, lag 0 was set as the concomitance of number of cases and rainfall (or temperature), lag 1 as the occurrence of cases within one month after rainfall (or temperature), and so on up to a time point where the correlation was not significant. It was used STATA software-version 11.2 to analyze data.

3. Results

3.1 Incidence of Dengue Fever: 2012-2016

For the period 2012-2016, there were reported 12,817 cases of autochthonous dengue in Araraquara, with incidence rates increasing until 2015 and then slowing down in 2016:

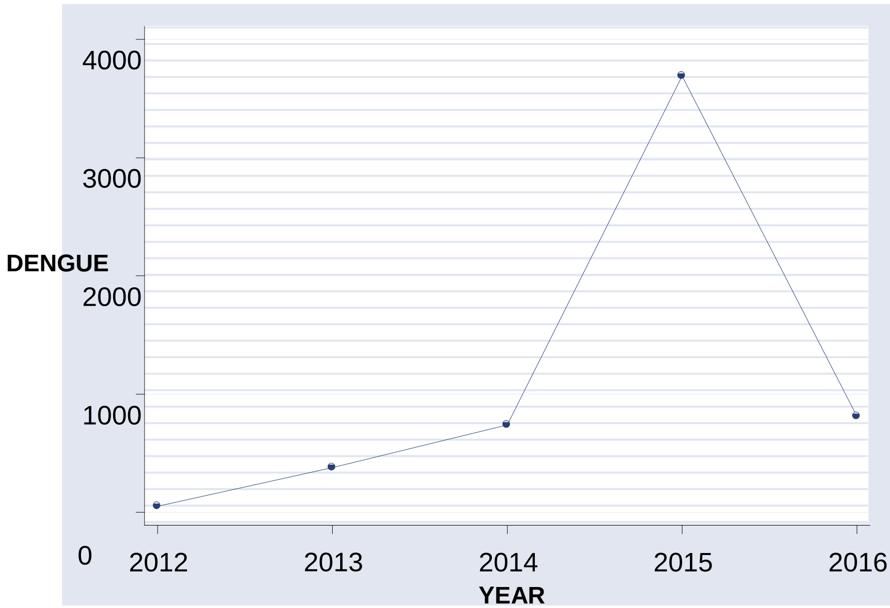

Figure 1. Dengue Incidence (x 100,000 Inhabitants). Araraquara-SP, Brazil, 2012-2016

March through May, i.e., from the last month of summer to the first two months of autumn, was the period with the highest numbers of autochthonous cases with 73% of total cases in 2012; 74% in 2013; 71% in 2014; 81% in 2015; and 68% in 2016.

3.2 Correlation between Number of Dengue Cases and Climatic Variables: 2012-2016

Table 1 shows the analysis of correlation (rs) between the number of dengue cases and climatic variables (temperature and pluviometry) at different time points (time-lag):

Table 1. Number of Dengue Cases Associated with Temperature and Rainfall Based on the Time-lag Concept for Estimating Spearman Correlation Coefficients (r_S). Araraquara-SP, Brazil, 2012-2016

Time-lag	rs: dengue-temperature	rs: dengue-rainfall
0	0.0559^{ns}	0.1608^{ns}
1	0.4056^{ns}	0.5944*
2	0.7972*	0.8881*
3	0.9231*	0.9231*
4	0.8322*	0.7063*
5	0.5315^{ns}	0.3427^{ns}

^{ns} non-significant; *significant

The correlation coefficients were shown when correlating climatic factors for a given month with the number of dengue cases in the same month, or 1, 2, 3, 4 and 5 months later, respectively to time-lag 0, time-lag 1, time-lag 2, time-lag 3, time-lag 4, and time-lag 5. Thus, the correlation of temperature with the number of dengue cases was significant 2 to 4 months later, and the correlation of rainfall with the number of dengue cases was significant 1 to 4 months later.

4. Discussion

A pattern of increasing dengue incidence was found in Araraquara each year from 2012 to 2015 until it peaked reaching the highest epidemic level and then slowed down in 2016 remaining at a level above the 2014 rate. The dengue incidence rate in 2015 was 3,660 cases per 100,000, which is well above the national average for 2012 (301 per 100,000), showing the magnitude of the dengue epidemic in the city (Bohm et al., 2016). Epidemic waves of dengue occurred from March to May. Ribeiro et al. (2006), in a study in the southeast city of São Sebastião, state of São Paulo, Brazil, reported epidemic waves occurring from April to June. However, a comparison of these findings is limited because both cities have different characteristics, and São Sebastião has attracted large numbers of migrants.

The monthly average temperature was 23.01 ℃ and average rainfall was 133.77 mm. The number of dengue cases was greater from March to May (late summer and early fall), which is corroborated by the findings of other studies (Ribeiro et al., 2006; Monteiro et al., 2009).

Vector proliferation seems to have been influenced by weather factors given the positive relationship with dengue transmission as described by Ribeiro et al. (2006). In addition, local conditions favorably influenced the *Aedes* mosquito cycle, possibly facilitated by human actions of improperly disposing wastes such as litter, old tires, and other materials. While dengue mosquitoes are more capable of surviving at high temperatures, the number of infected people is unsurprisingly greater during the rainy season because artificial collections of water make the environment more favorable for the breeding of the transmitting mosquito.

In Brazil, it is expected to an increased number of dengue cases at the start of the year (with a peak between March and April), in hot and humid weather. In view of the COVID-19 scenario (with a peak between April and May), there is a common period (April) in which the two diseases could affect the population and, consequently, overburden the country ́s Unique Health System (Lorenz et al., 2020).

For preventing mosquito breeding and, consequently, dengue fever, local population should be actively involved. People need to have basic knowledge and understanding of their environment and take the measures required to prevent mosquito-borne diseases. It should be done along with epidemiological surveillance and control measures carried out by public health authorities. Understanding dengue vector dispersion and density is key for entomological surveillance and dengue control strategies using effective technology should aim at reducing breeding sites.

The positive correlation between number of dengue cases and climatic variables, considering time-lags at which temperature and rainfall contributed to the emergence of new cases, is a major finding that could inform vector control planning strategies. Humidity and temperature can determine the proper condition to the development of the insects (El-Sayed & Kamel, 2020).

Duarte et al. (2019) emphasized that health-related events are closely linked to the environmental conditions and that ecological studies are of great importance. There is a need of integrated action between hot, humid season and dengue surveillance services. Higher temperature and rainfall create a scenario with more favorable conditions for emergence of dengue fever and other diseases borne by *Aedes aegypti* mosquitoes.

5. Conclusions

During the period from 2012 to 2016, the incidence rates of dengue increased until 2015 and then slowed down in 2016.

There was a significant correlation coefficient between the number of dengue cases and climatic factors. Considering time- lags at which they favored the occurrence of new cases: 2 to 4 months later for high temperature and 1 to 4 months later for rainfall.

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