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ORIGINAL ARTICLE

INFLUENCE OF THE WEATHER ON THE OCCURRENCE OF DENGUE IN A TRIPLE-BORDER BRAZILIAN MUNICIPALITY

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ABSTRACT

Objective: to analyze the temporal evolution of the incidence of dengue and its correlation with climatic variables in Foz do Iguaçu, a triple-border Brazilian municipality, in the period from August 2006 to July 2016. Method: a descriptive and analytical study conducted in 2018. Secondary data obtained from the health information systems were used. Time analysis was employed and a simple linear regression test was applied to assess the correlation between the dengue incidence rates and the climatic variables. Results: the epidemic years represented 60% of the period studied. There was a positive correlation between incidence of dengue and mean relative humidity in the air (r=0.276; p=0.025), mean temperature (up to two months before r=0.288; p=0.014) and pluviosity (up to three months before r=0.308; p=0.008). Conclusions: the climatic variables identified as with a positive relationship can support prediction and control of the dengue epidemic.

DESCRIPTORS: Dengue; Aedes; Weather; Epidemics; Border Areas.

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INTRODUCTION

Dengue belongs to the list of diseases caused by viruses, being transmitted by and arthropod called *Aedes aegypti*. This virus belongs to genera *Flavivirus*, family *Flaviviridae*, and its infection is caused by four flavivirus serotypes: DEN-1, 2, 3 and 4, which produce specific serotype immunity and can manifest as classical dengue, dengue with alert signs or severe dengue. In 2011, the disease was responsible for approximately 230 million infections, with 25,000 fatal cases. In recent decades, its incidence has shown a significantly accentuated global advance, affecting 3.6 billion people, mainly in the population living in urban centers from tropical and subtropical regions(1-2).

Currently, dengue is globally considered as the most important arbovirus in terms of morbidity, lethality and economic implications, despite the numerous eradication or control programs that have been implemented. It occurs practically in all tropical and subtropical regions of the planet. In the American continent, it has shown an increasing trend in the number of notifications(3-5).

The environmental conditions (especially climate) and the inefficiency of the public policies aimed at the environment have contributed to the increase and proliferation of the *Aedes aegypti* mosquito, which characterizes a serious public health problem, with a more significant impact in tropical countries(3-5).

A number of studies indicate that climatic variations related to increased temperature and pluviosity contribute to increasing the number of breeding sites, thus facilitating development of the vector. The current situation of dengue in Brazil is a matter of great concern for the health authorities, due to the difficulties encountered in controlling the vector, which is the main action for preventing the disease, as well as to the insufficient installed capacity of the health services to assist the individuals affected with the severe forms of the disease. However, the impact of social factors, such as housing quality and income, has also been predicted to control the vector(4,6-8).

In the state of Paraná, dengue showed a rapid increase in the number of cases and an important expansion throughout the territory since confirmation of the first autochthonous cases in 1993(8). Foz do Iguaçu, a city in Paraná limiting with Paraguay and Argentina, corroborates the situation in the state, recording cases of dengue since 1998. In the last 10 years, on a cyclical basis, the city has suffered several epidemics and an increase in the number of severe cases, culminating in an increase in hospitalizations and deaths, causing a high demand for care and hospitalization of patients in the health services, in addition to indicating a worrying trend for the next years. This scenario turns dengue into the main concern among the municipality's endemic diseases, representing a serious Public Health problem for the region(9-10).

The problem of dengue in Foz do Iguaçu is aggravated due to its geographic and social characteristics, namely: its strategic location as a triple-border city with different socioeconomic realities, intense flow of people between the countries, and a record of a fluctuating population of more than one million people among tourists, truck drivers and inhabitants living in other cities who work in Foz do Iguaçu. There is also coexistence of more than 80 ethnic groups with different cultural realities. Allied to these characteristics, the municipality presents a climate with different high temperatures and frequent rainfall(9-10).

In this context, the objective of this study was to analyze the temporal evolution of the incidence of dengue and its correlation with climatic variables in Foz do Iguaçu, a triple-border Brazilian municipality, in the period from August 2006 to July 2016.

METHOD

The study was conducted in the city of Foz do Iguaçu-PR, a triple-border region (Brazil, Paraguay and Argentina). The municipality has a population of 263,647 inhabitants[9].

This is a descriptive and analytical study, carried out using temporal analysis techniques and statistical tests based on secondary data of confirmed cases of dengue and climatic variables, which included the following: total rainfall in millimeters (mm), relative humidity in the air (%) and mean maximum temperature in degrees Celsius (°C), in the period from August 2006 to July 2016.

The data were obtained from the Information System for Notifiable Diseases (*Sistema de Informação de Agravos de Notificação*, SINAN) and from the Paraná Meteorological System (*Sistema Meteorológico do Paraná*, SIMEPAR), made available by the Health Surveillance Service of the Foz do Iguaçu Municipal Health Secretariat.

The incidence of dengue was calculated by means of the following formula: (number of cases notified/total population in the city) x 100,000, distributed by dengue epidemiological year, which starts in August of one year and ends in July of the following year, a criterion commonly used in dengue studies. The population for calculation of the incidence rates was obtained from the 2000 and 2010 demographic censuses of the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística*, IBGE), using the census population from 2000 to calculate the years 2006 to 2009, and the 2010 census data for calculations of the years 2010 to 2016. The annual incidence values were classified into epidemic or non-epidemic years, considering epidemic years those with an incidence equal to or greater than 300 cases per 100,000 inhabitants.

For the analysis of the climatic factors, the monthly mean maximum temperature in degrees Celsius (°C), monthly mean rainfall in millimeters (mm) and monthly mean relative humidity in the air (%) in the period from May 2006 to July 2016 were considered.

Descriptive analyses were performed through the temporal distribution of dengue incidence and of the climatic variables. Temporal graphs were prepared comparing the monthly climatic variables between the epidemic and non-epidemic years, and Mann-Whitney's statistical test was applied to verify significant differences in the climatic data between the epidemic and non-epidemic years. The GraphPad Prism program, version 8, was used to prepare the graphs.

The correlation between the incidence of dengue and the climatic variables was analyzed by applying a simple linear regression test, considering the values of the simultaneous months of occurrence, as well as one, two and three months before occurrence of the incidence of the disease. This time interval was considered due to factors such as embryonic development period, larval hatching time, larvae and pupae development time, and extrinsic and intrinsic mosquito incubation periods.

The statistical tests were performed by using the Minitab program, version 18.1, and considering $p<0.05$ as significance criterion. This study was approved by the Committee of Ethics in Research with Human Beings of the Ribeirão Preto Nursing School at the University of São Paulo, under opinion No. 2,073,482.

RESULTS

During the 10 years analyzed, it was verified that the epidemic years surpassed the non-epidemic years, with six epidemic years (2007, 2010, 2011, 2013, 2015 and 2016) and four non-epidemic years (2008, 2009, 2012 and 2014), that is, 60% of the period studied was epidemic. Incidence of the disease in the epidemic years was high, exceeding 3,000 cases/100,000 inhabitants (Figures 1A and 1B).

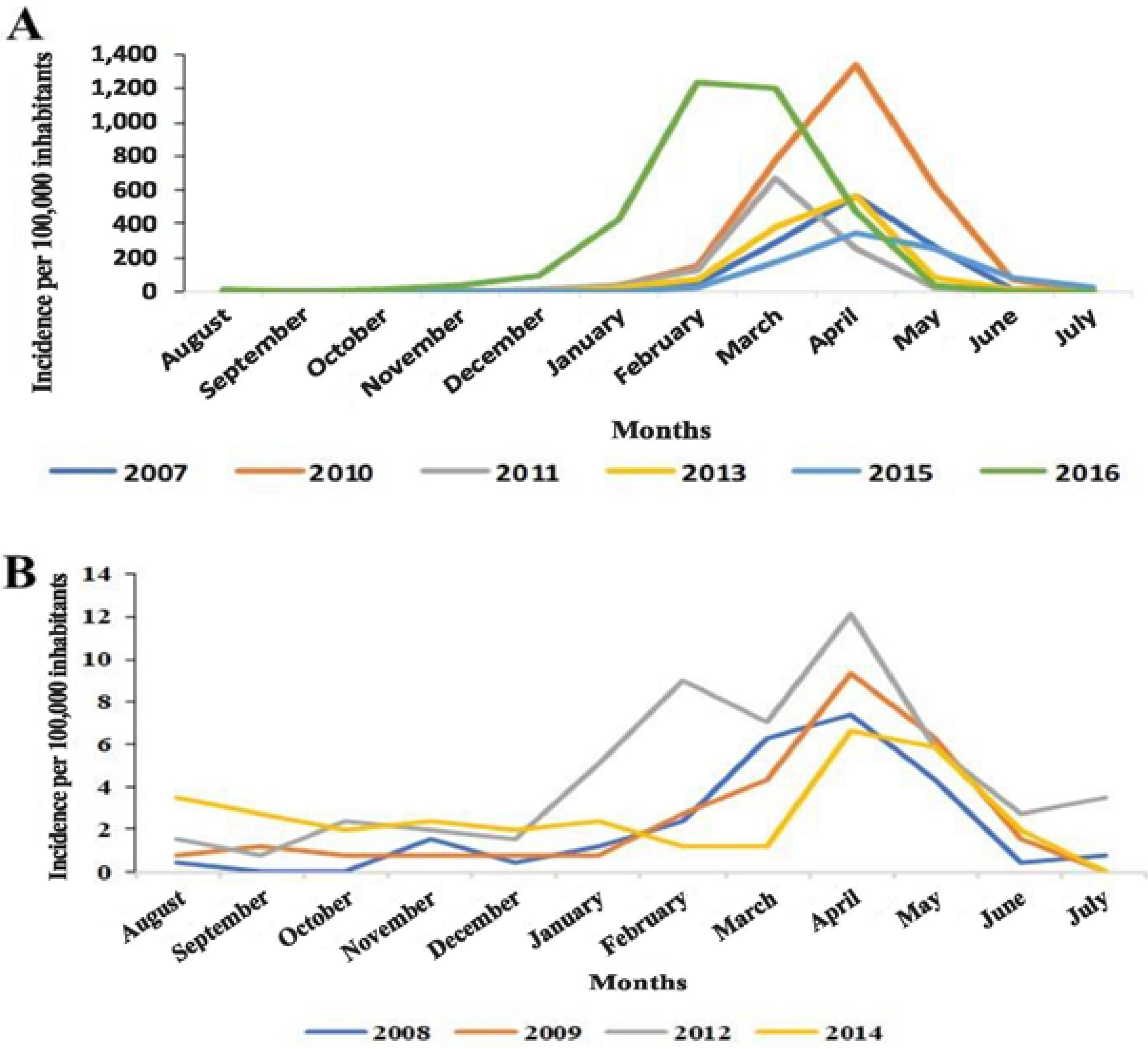

Figure 1 - Temporal distribution of dengue incidence: A) Monthly incidence rate (x 100,000 inhabitants) for the epidemic years; B) Monthly incidence rate (x 100,000 inhabitants) for the non-epidemic years. Foz do Iguaçu, PR, Brazil, 2018
Source: The authors (2018)

The largest epidemic of the historical series was in the 2009/2010 epidemic year, with an incidence value over 3,000 cases for every 100,000 inhabitants. The periods between March and May were the ones with the highest incidence values, except in 2015/2016, when anticipation of the epidemic is verified with an increase in incidence starting in November and maximum peak of the disease in the months of February and March (Figure 1A). In the non-epidemic years, incidence was low, not exceeding 14 cases for every 100,000 inhabitants (Figure 1B).

When comparing the data in the epidemic years to those of the non-epidemic years, the incidence rate was significantly higher in the period from February to June in the epidemic years (Figure 2A). The mean maximum temperature presented a significant reduction ($p<0.05$) in the epidemic years during January and February (summer) when compared to the same months in the non-epidemic years (Figure 2B). Pluviosity presented many fluctuations, both in the epidemic and in the non-epidemic years. However, it presented a significant increase only in December in the epidemic years (Figure 2C). It was also noticed that relative humidity in the air was higher in the epidemic years, with a significant difference only in the month of February for the epidemic years (Figure 2D).

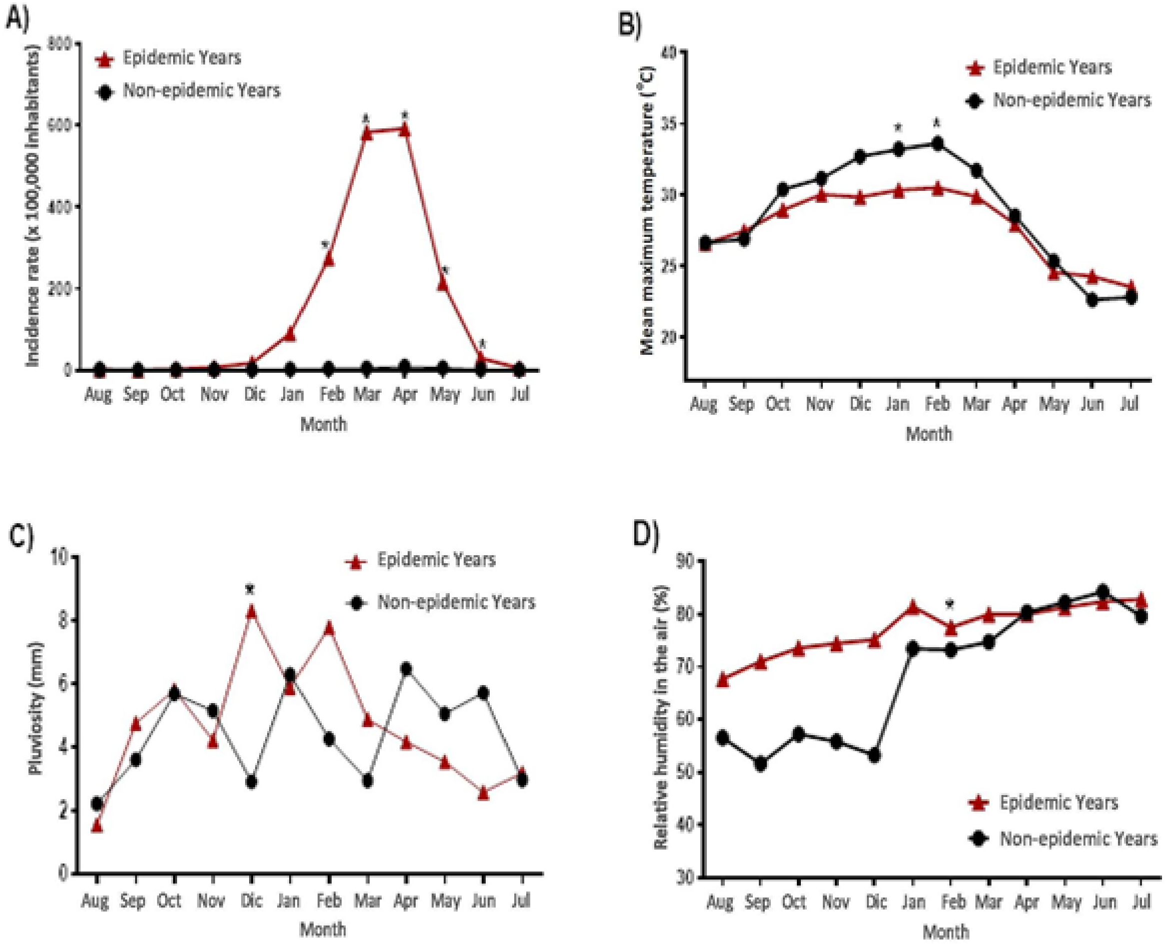

Figure 2 - Temporal distribution of dengue incidence and of climatic factors for the epidemic and non-epidemic years: A) Incidence rate (x 100,000 inhabitants); B) Mean maximum temperature (0C); C) Pluviosity (mm); D) Relative humidity in the air (%). Foz do Iguaçu, PR, Brazil, 2018
Key: *Significant difference when p<0.05. Source: The authors (2018)

There was a significant and positive correlation (p<0.05) of the dengue incidence rate for the epidemic years with the following variables: relative humidity in the air (simultaneous period), rainy days, mean maximum temperature (with intervals of one and two months before) and pluviosity (with intervals of one, two and three months before) (Table 1).

Table 1 - Results of the simple linear regression between the dengue incidence rate and the climatic factors, for the epidemic years. Foz do Iguaçu, PR, Brazil, 2018

Variables	**Simultaneous**		**1 month before**		**2 months before**		**3 months before**	
	r	**p**	**R**	**p**	**r**	**p**	**r**	**p**
Relative Humidity in the air	**0,276**	**0,025**	0,178	0,151	0,153	0,214	0,099	0,419
Mean maximum temperature	0,127	0,294	**0,411**	**0,005**	**0,288**	**0,014**	0,116	0,327
Pluviosity	0,061	0,607	**0,264**	**0,024**	**0,373**	**0,001**	**0,308**	**0,008**

Source: Prepared by the author based on information from the SINAN, SIMEPAR (2018).

In the non-epidemic years, a significant and positive correlation (p<0.05) was verified between the dengue incidence rate and the mean maximum temperature (with a three-month interval). The other variables analyzed did not present a significant correlation with the incidence of dengue (Table 2).

Table 2 - Results of the simple linear regression between the dengue incidence rate and the climatic factors, for the non-epidemic years. Foz do Iguaçu, PR, Brazil, 2018

Variables	**Simultaneous**		**1 month before**		**2 months before**		**3 months before**	
	r	**p**	**R**	**p**	**r**	**p**	**r**	**p**
Relative Humidity in the air	0,139	0,342	0,113	0,444	0,068	0,642	0,137	0,353
Mean maximum temperature	0,065	0,66	0,116	0,43	0,035	0,107	**0,303**	**0,036**
Pluviosity	0,138	0,346	0,124	0,397	0,042	0,776	0,137	0,351

Source: Prepared by the author based on information from the SINAN, SIMEPAR (2018).

DISCUSSION

This study revealed that, in the epidemic years, there is a positive correlation between the dengue incidence rates and the following climatic variables: relative humidity in the air in a simultaneous period, mean maximum temperature with intervals of one and two months before in relation to the high rates, and pluviosity with intervals of one, two and three months before.

The weather conditions generally show a positive relationship with dengue transmission, when the increase in rainfall and temperature in a given month partially explained the increase in the number of dengue cases two to three months later[11-12]. This corroborates the findings of this research since, in the epidemic years evaluated, the incidence rates presented a positive correlation with the temperatures (close to 30°C) and with pluviosity, up to two and three months before, respectively (Figures 2A, 2B and 2D).

Regarding relative humidity in the air, the regression indicated a simultaneous and positive relationship with high dengue incidence, showing that humidity values over 70% contribute to the increase in the number of cases (Figures 2A and 2C). Another study also showed that relative humidity in the air, mean maximum temperature and pluviosity were significant for the generation of risk prediction maps[13].

The result of this study showed that the mean maximum temperature was higher in the summer months in the non-epidemic years, although the statistical analysis only showed significance in the months of January and February in these years. The Dengue Climate Alert System, created by the Research Center of the Federal University of Paraná, establishes that temperatures between 22°C and 30°C present a high risk for dengue epidemics, corroborating the result of this study, since the mean maximum temperature in the summer months in the non-epidemic years exceeded 30°C, above the desirable limits for mosquito proliferation, while the mean maximum temperature in the epidemic years remained between 25°C and 30°C, values considered ideal for high risk of dengue epidemics[14].

It is to be noted that several research studies indicate that the use of this dengue early climate alert framework associated with the epidemiological data can be useful to control or contain potentially exponential dengue epidemics[11-12,15-16].

With the exception of relative humidity in the air, which was correlated with dengue in a simultaneous period, the other climatic predictors were correlated with the disease with intervals of one, two and even three months before the high incidence rates in the case of pluviosity. The weather influence plays a special role in reproduction of the virus and of the mosquito that serves as its vector[16].

This result corroborates others which show that, in Brazil, the number of dengue cases increased during the first four months of each year (period of high pluviosity) and decreased between June and September (less pluviosity). Even with differences in rainfall dynamics in the several regions of the country, the higher incidence of the disease and levels of vector infestation coincide with the rainy months or close intervals that varied from one to three months[4,11-12,17].

It is to be noted that this time between the increase in temperature and pluviosity and the increase in the incidence rates is justified as being the necessary time space due to the biology of *Aedes aegypti*, the spatial diffusion of this vector and pf the dengue virus, and the time until the positive cases are recorded in the information system[11-12,18-19].

The data found in this study reinforce that the climatic factors, especially temperature and pluviosity, improve dengue outbreak predictions and could be easily incorporated into an early monitoring system for dengue outbreaks three months in advance[20].

Eradication of dengue in humid tropical regions proves to be extremely difficult through classical methods of mosquito control; there is an urgent need to explore the natural vulnerabilities of the dengue vectors such as habitat and climatic limitations, with new techniques for transgenic and symbiotic bacterial control to develop future dengue control and elimination strategies[6]. The advance provided by this study is the confirmation of climatic variables (temperature, pluviosity and relative humidity in the air) as predictors of dengue in an international border tropical region.

One of the study limitations was the use of data only from the city of Foz do Iguaçu. For stronger and future analyses, it is suggested that climatic analyses of the environment be included, even of the neighboring cities in Paraguay and Argentina.

CONCLUSION

The findings of this research showed that temperature, pluviosity and relative humidity in the air are confirmed as predictors of dengue for the region under study.

Thus, understanding the temporal distribution of dengue incidence together with the climatic factors assessed is an important tool in dealing with the problem, with the possibility of being used to prevent epidemics of dengue and of other arboviruses transmitted by *Aedes aegypti*. The predictive time evidenced in the study is opportune for the elaboration of a surveillance system with relevant implications for public health, capable of assisting in predicting dengue epidemics.

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Role of Authors:
Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work - Meira MCR, Nihei OK, Moschini LE, Arcoverde MAM, Britto A da S, Muñoz, SS; Drafting the work or revising it critically for important intellectual content - Meira MCR, Silva Sobrinho RA da, Muñoz, SS; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved - Meira MCR. All authors approved the final version of the text.

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