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Potential influence of climate variability on dengue incidence registered in a western pediatric Hospital of Venezuela

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Abstract. Climate change and variability is affecting human health and disease direct or indirectly through many mechanisms. Dengue is one those diseases that is strongly influenced by climate variability. In this study we assess potential associations between macroclimatic variation and dengue cases in a western pediatric hospital of Venezuela in an eight-year period. Between 2001 and 2008, 7,523 cases of dengue were reported in the Hospital Agustin Zubillaga, Barquisimeto, Venezuela. Climatic periods marked a difference of 23.15% in the mean incidence of cases, from El Niño weeks (-14.16% of cases below the mean incidence) to La Niña months (+8.99% of cases above it) ($p=0.0001$). Linear regression showed significantly higher dengue incidence with lower values of Oceanic Niño Index (ONI) (El Niño periods) and lower dengue incidence with higher values of ONI (La Niña periods) ($p=0.0002$). As has been shown herein, climate variability is an important element influencing the dengue epidemiology in Venezuela. However, it is necessary to extend these studies in this and other countries in the region, because these models can be applied for surveillance as well for prediction of dengue.

INTRODUCTION

Dengue fever is one of the most important viral diseases in the world. Dengue viruses are among the most widely distributed and significant arthropod-borne viruses (Arboviruses) affecting humans. Their predominant mosquito vector, *Aedes aegypti*, is endemic at most of the tropical and subtropical regions of the world. There, they can cause seasonal epidemics of varying populational size (Johansson *et al.*, 2009).

Global emergence and resurgence of dengue can be attributed to multiple factors including urbanization, transportation and changes in human migration and behavior, resulting in dengue increase as the second most important vector-borne disease, after malaria, in terms of human morbidity and mortality (Gubler, 1998; Mackenzie *et al.*, 2004).

It has been estimated that each year 50 to 100 million people suffer from dengue and that two-fifths of the human population are at risk. Geographical distribution of dengue and the potential occurrence of life-threatening dengue hemorrhagic fever (DHF) have expanded dramatically in recent decades (Guzman & Kouri, 2002). Part of this disease expansion is due to societal changes such as population growth, urbanization, transport development and changing habitats and behavior that can increase the risk of disease (Patz *et al.*, 2000; Guzman & Kouri, 2002; Hales *et al.*, 2002; Brunkard *et al.*, 2008).

These complex interacting factors can be also influenced by climate, as the ecological niches of the vector, *Ae. aegypti*, can be favoured and then its population able to transmit disease can increase significantly. Different studies have implied that cold temperature can limits its lifecycle, then acting as an influencing factor on its distribution (Beebe *et al.*, 2009). Then increases in temperature, as well global warming, can potentially increase mosquito populations and dengue incidence (Reiter, 1996; Hsieh & Chen, 2009). This has been particularly influenced in South America by the El Niño Southern Oscillation (ENSO) phenomena. This climatic anomaly consisted of a periodic change in the atmosphere and ocean conditions in the tropical Pacific region. It is manifested in the atmosphere by changes in pressure and in the ocean by warming or cooling of water surface at the tropical Eastern Pacific Ocean. El Niño is the name given to the period when water in that region is warmer than normal (means) while La Niña is the period when is colder than normal (Brunkard *et al.*, 2008).

In countries with tropical temperatures, such as Venezuela, this has been previously reported (Rifakis *et al.*, 2005). However, given the incidence of dengue, its increase and its multiple consequences in this as in other Latin American countries, particularly due to several epidemics of DHF since 1989 (Barrera *et al.*, 2000), surveillance and studies reporting on the potential influence of climate variability on dengue incidence are of utmost importance. For these reasons in this study we assess potential associations between macroclimatic variation and dengue cases in a western pediatric hospital of Venezuela in an eight-year period.

MATERIALS AND METHODS

Pediatric Hospital Agustin Zubillaga, Barquisimeto, Lara state, Western Venezuela, is a pediatric hospital of the Lara state (the main). The Department of Epidemiology is in charge of surveillance and laboratory confirmatory follow-up of all patients suspected with dengue. This is registered in a weekly basis.

For this study, the epidemiological data was constituted by all the weekly records of confirmed dengue cases in children (<18 y-old) from the epidemiological records were collected for the period 2001-2008. Diagnosis was initially clinically made and then serologically (ELISA) and virologically (viral isolation) confirmed by the reference public health laboratory system, according to the national control program for dengue fever of the Ministry of Health.

The climatic data was based on one global macroclimatic index, the Oceanic Niño Index (ONI), classifying the climatic periods according to National Oceanographic and Atmospheric Administration (NOAA, USA) classification, and months were categorized as El Niño, Neutral and La Niña to establish differences in the dengue incidence according those periods.

Statistical analysis

Descriptive statistics were generated for the epidemiological and climatic data (means, standard deviations, SD). Qualitative and quantitative comparisons were made for climatic periods. Linear regression models were used for determining potential associations. Statistical significance was defined as $p < 0.05$. Statistical analyses were performed on GraphPad Prism v.4.0®.

RESULTS

During the study period (2001-2008) 7,523 cases of dengue were diagnosed and reported. The mean number of dengue cases per year was 940±353 (±SD), while the mean number of dengue cases per week was 18±11 (range 0-68 cases/week). These weekly variations generated different endemic levels for the year 2008. In this year 5 weeks were located at epidemics level compared with the previous 7 years, which allowed to build the weekly endemic levels (0+DE [blue], 0 [pink] and 0-DE [green]) (Figure 1).

During the considered climatic periods a net difference of 23.15% was observed in the mean incidence of cases, from El Niño weeks (-14.16% of cases below the mean incidence) to La Niña months (+8.99% of cases above the mean incidence) (χ^2=31.15; p=0.0001) (Figure 2).

Linear regressions between the ONI index and the dengue incidence showed a significant association. With higher values of ONI (above 0, El Niño periods) lower incidence of dengue was observed and with lower values of ONI (below 0, La Niña periods) higher incidence of dengue was observed (r^2=0.032; F=13.79; p=0.0002) (Figure 3).

DISCUSSION

El Niño Southern Oscillation (ENSO) is considered a periodic change in the atmosphere and ocean of the tropical Pacific region, manifested in the atmosphere by changes in pressure and in the ocean by warming or cooling of sea surface at the tropical Eastern Pacific Ocean.

Two main phases constituted the phenomena of ENSO, El Niño, the period when water in that region is warmer than the means (of the temperature during the previous period) while La Niña is the period when the water is colder than the means (of the temperature during the previous period). These periods could be measured by the Oceanic Niño Index (ONI), positives values indicate El Niño phase and negative values La Niña phase. Usefulness of this index in the context of climate variability impact on dengue has been previously reported by us (Rifakis *et al.*, 2005). We found that the highest case increase was significantly associated with La Niña. Linear regression models found a statistically significant association between dengue fever and rainfall abnormalities in Caracas (p=0.0319), as well with temperatures (p=0.0001) (Rifakis *et al.*, 2005).

Results in the current study evidenced associations between climatic conditions and dengue epidemiology in Barquisimeto, Venezuela, which was reflected with a higher number of dengue cases in the pediatric hospital of the region when La Niña period was predominant. This would be explained by the existence of environmental conditions influenced by that macroclimatic change favorable for *Ae. aegypti* reproduction, particularly in the context of urban climatic change (Sutherst, 2004). La Niña in this region of Venezuela

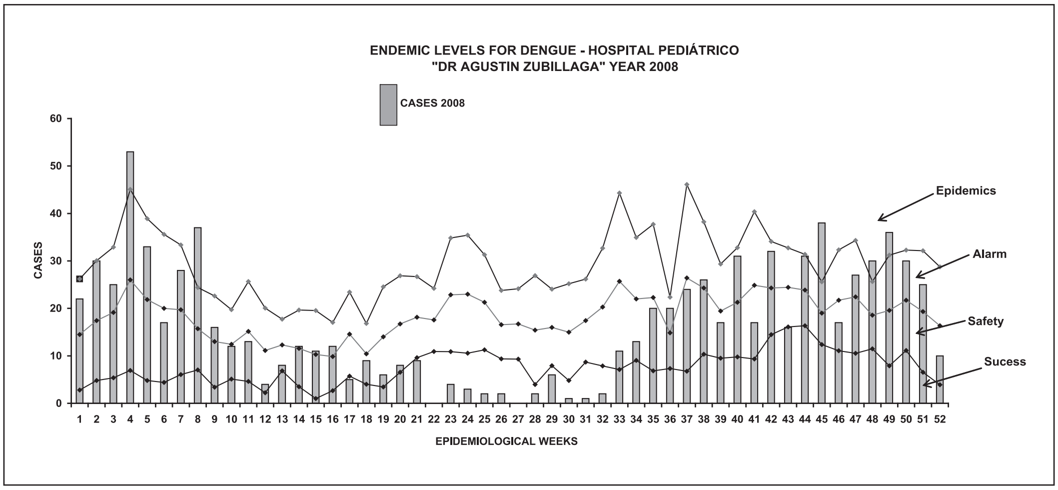

Figure 1. Endemic levels for dengue fever at the Pediatric Hospital, 2008 (endemic levels were calculated with the last previous 7 years, 0+DE [blue], 0 [pink] and 0-DE [green])

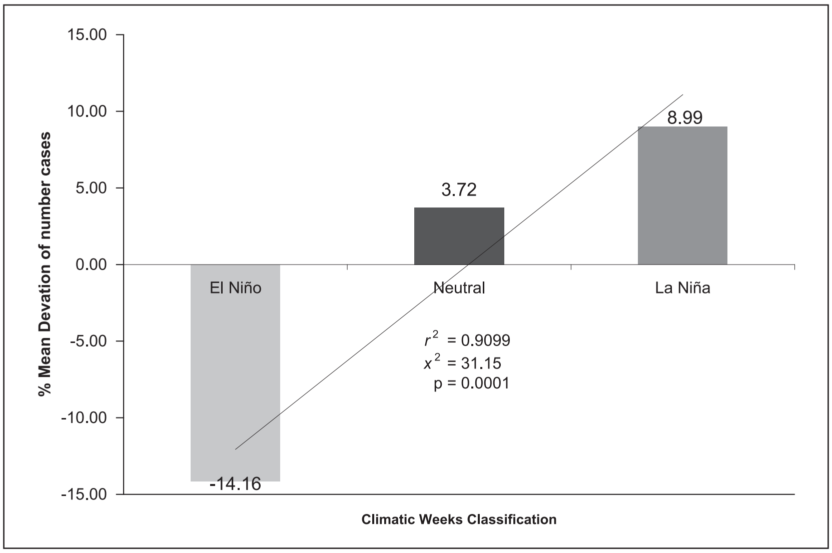

Figure 2. Difference in the mean incidence of cases, from El Niño and La Niña months and weeks

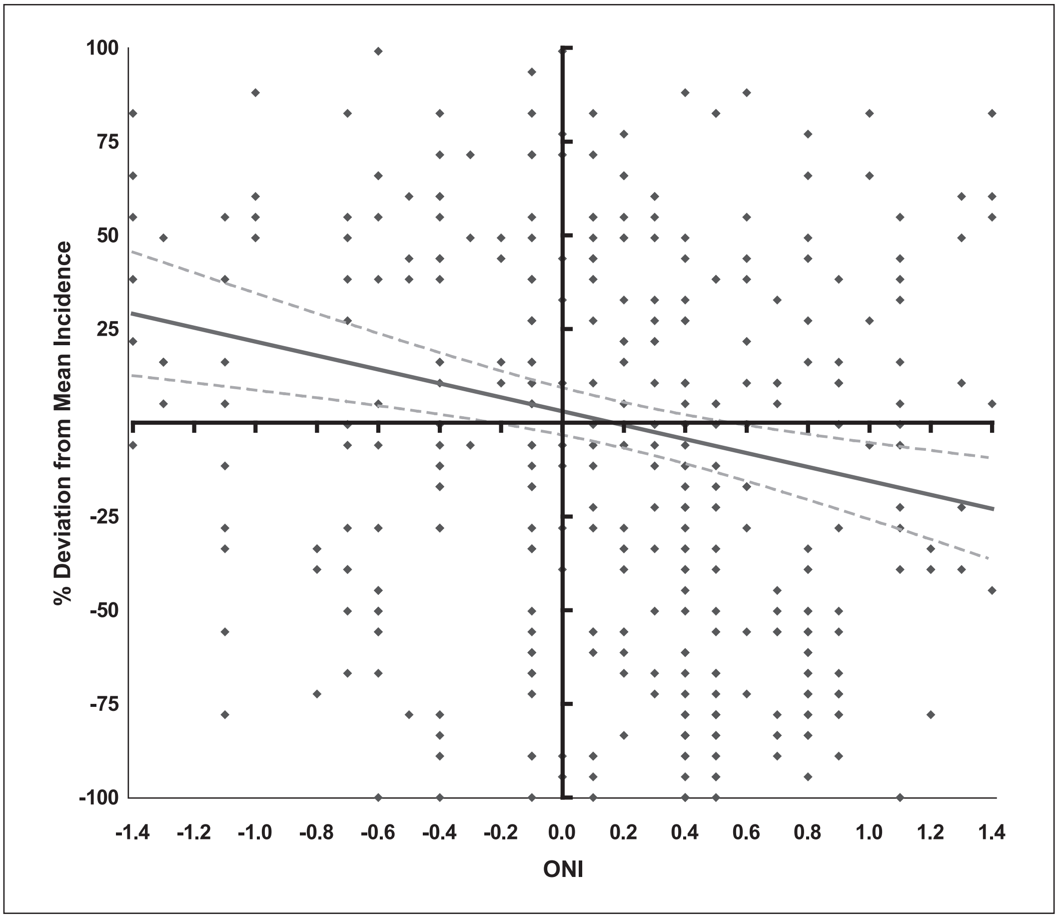

Figure 3. Linear regression between ONI and dengue incidence variations in the Pediatric Hospital, Barquisimeto, Venezuela, 2001-2008

influenced microclimatic conditions such as increase in the rainfall, humidity and lowering temperatures. This increase the collections of water at any type of water-holding container in urban settings (tree holes or leave as well man-made cisterns, discarded bottles and tires, tree holes or leave as well man-made cisterns, discarded bottles and tires), which are suitable for disposal of eggs of *A. aegypti*, then making those favorable conditions for more breeding habitats for the mosquito, then increasing the available population to vector dengue viruses.

Man-made habitats are abundant near urban populations, where food supply (human blood) for gravid female mosquitoes is also plentiful. In these environments, climatic variables such as temperature, humidity, and precipitation during La Niña in Barquisimeto significantly influence mosquito development and survivorship (Watts *et al.*, 1987).

From those climatic variables, temperature is crucial. It affects the rate of development in different mosquito life stages, as well as dengue viral development (Thu *et al.*, 1998). Different studies have shown that mosquito survival rates are temperature dependent. Additionally, humidity and in general the presence of water is necessary for egg laying and hatching and for larval survivorship, and relative humidity affects adult mosquito mortality.

Herein we have found that changes in microclimatic conditions at those urban niches where *Ae. aegypti* can develop, can be affected by changes in macroclimatic conditions such as global climate change and global climate variability.

Several studies have predicted that global climate change could increase the incidence of dengue epidemics (Phillips, 2008). An empirical model of worldwide dengue distribution, reported that annual average vapor pressure (a measure of humidity) was the single climate factor that best predicted dengue fever distribution. They also found that if humidity remained at 1990 levels into the next century, a projected 3.5 billion people would be at risk of dengue infection in 2085, but if humidity increases as projected by the Intergovernmental Panel on Climate Change, 5.2 billion people would be at risk (Hales *et al.*, 2002; Schwartz *et al.*, 2008).

Studies in Puerto Rico have concluded that year-to-year variability in dengue cases is positively related to temperature, but only weakly associated with local rainfall and an index of El Nino Southern Oscillation (ENSO) (Jury, 2008), however in our study we found a significant association with the ONI, an index of ENSO.

In Mexico a study showed that dengue incidence increases 2.6% one week after every 1 degree Celsius increase in weekly maximum temperature and increased 1.9% two weeks after every 1 cm increase in weekly precipitation (Guzman & Kouri, 2002; Hales *et al.*, 2002).

We have previously reported in Venezuela significant associations between dengue epidemiology and climatic variability (Rifakis *et al.*, 2005). In these studies the ENSO cold phase, La Niña, has been linked to an increased incidence of disease, as occurred in our current study, explained by higher precipitations means as well for a favorable temperatures for vector and transmission.

These results linking potential impacts of climate variability with dengue epidemiology should be considered in public health policies, particularly those focused on surveillance, forecast and prediction of disease.

In São Paulo, Brazil, research experiences have found that the relation between climatic factors, vector and disease can be employed in planning and undertaking dengue surveillance and control activities (Dibo *et al.*, 2008). In fact, that relationship allows the use of climate information for early detection of epidemics. This will allow more effective prevention strategies than currently exist (Depradine & Lovell, 2004).

Despite the limitations of our study (e.g. lack of local temperature, rainfall and humidity data), results show that in this 8-year study more than 14% of reduction of disease mean incidence is observed during

El Niño (dry season), and with La Niña (wet season) almost 9% of increase is observed. Furthermore, is necessary to extend the deepness of these studies in this and other countries in the region, because these models can be applied to surveillance data for predicting trends in dengue incidence.

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