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ORIGINAL RESEARCH

Estimating Effects of Temperature on Dengue Transmission in Colombian Cities

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Abstract

BACKGROUND Dengue fever is a viral disease that affects tropical and subtropical regions of the world. It is well known that processes related to virus transmission by mosquitoes are highly influenced by weather. Temperature has been described as one of the climatic variables that largely governs the development and survival of mosquito eggs as well as the survival of all insect stages. Previously, we noted that high temperatures in the Colombian city of Riohacha negatively affect the establishment of dengue virus (DENV) infection in mosquitoes; in Bello and Villavicencio cities, which have lower average temperatures, DENV infection rates in mosquitoes are positively associated with a gradual increase in temperature. Here, we test the hypothesis that a similar effect of temperature can be detected in the incidence in the human population inhabiting dengue-endemic cities in Colombia.

OBJECTIVE Our objective was to evaluate the effect of climate variables related to temperature on DENV incidence in human populations living in DENV-endemic cities in Colombia.

METHODS Epidemiologic data from the Instituto Nacional de Salud from 2012-2015 and 7 variables related to temperature were used to perform Spearman rank sum test analyses on 20 Colombian cities. Additionally, locally estimated scatterplot smoothing analyses were performed to describe the relationship among temperatures and incidence.

FINDINGS Results indicated that Colombian cities with average and maximum temperatures greater than 28°C and 32°C, respectively, had an inversely related relationship to DENV incidence, which is in accordance with areas where higher temperatures are recorded in Colombia.

CONCLUSION Climatic variables related to temperature affect dengue epidemiology in different way. According to the temperature of each city, transmission might be positively or negatively affected.

KEY WORDS climatic variables, correlation analysis, correlation coefficient, dengue, incidence, temperature.

INTRODUCTION

Dengue fever is a viral disease present in tropical and subtropical regions of the world. It is estimated that around 390 million infections occur each year, but only about 96 million people manifest the infection clinically.[1] The virus is transmitted by mosquitoes belonging to *Aedes* genus, of which the most important species is *Aedes aegypti* because of its high anthropophily.[2,3] Once the mosquito feeds on a viremic human, the virus establishes the infection in the midgut of the insect, where it then disseminates (or not) from the midgut to other tissues, including the salivary glands. Those mosquitoes that do allow virus

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infection, replication, dissemination, and ultimately transmission of the virus are known as competent vectors of the virus.[4]

It is well known that processes related to virus transmission are influenced by weather. Numerous associations between different climatic variables and dengue cases have been broadly described (as reviewed by Morin et al[5]). However, temperature is one of the most studied variables and has been described as the climatic variable that largely governs the development and survival of mosquito eggs as well as the survival of all stages of the insect.[6,7] Results of these studies lend evidence to the idea that the optimal temperature for mosquito development at all stages ranges from approximately 20°C-30°C.[8-10]

In addition to mosquito life traits, temperature affects the course of infection within the mosquito, and it has been noted that an increase of temperature leads to a reduction in the extrinsic incubation period.[11] Moreover, overall dengue virus (DENV) infection proportions in mosquitoes are believed to be influenced by low and high temperatures.[12] Recently it was reported that daily fluctuations of low and high temperatures have a significant effect on development and DENV infection rates of mosquitoes, where large temperature fluctuations are correlated with slower mosquito development and low infection rates,[13-16] but such fluctuations at low mean temperature accelerate DENV transmission by mosquito.[17]

Based on this, a large amount of evidence supports a relationship between temperature and dengue incidence in human populations (as reviewed by Morin et al,[5] Naish et al,[18] and Junxiong and Yee-Sin[19]). Fan et al[20] developed a meta-analysis indicating an increase in the risk of dengue fever through an increase in temperature, where mean temperature was found to be more important than maximum and minimum temperatures. Interestingly, from 29°C the odds ratio of dengue risk began to decline,[20] suggesting a nonlinear effect of temperature.

In agreement with this, we recently reported that temperature differentially affects the DENV infection of mosquitoes in 3 Colombian cities.[21] We found that high temperatures in the city of Riohacha negatively affected infection by DENV, whereas in Bello and Villavicencio municipalities, which have lower average temperatures, DENV infection rates in mosquitoes were positively associated with a gradual increase in temperature.[21] As with any mosquito-borne virus, infection rates in the mosquito population are necessarily tied to transmission to the human population. Thus, we wished to determine if temperature-related variables correlated to dengue incidence patterns, so we investigated the correlation between climatic variables related to temperature of 20 Colombian cities and dengue incidence of those cities. Our aim was to describe a general pattern in dengue incidence and temperature that can be further applied at the national level to develop a temperature-stratified risk map of Colombia to improve disease control strategies and make better use of resources. With this in mind, we developed a model of temperature behavior through a range of temperature values to be applied to different regions of Colombia.

MATERIALS AND METHODS

Epidemiologic Data. We collected epidemiologic data about dengue cases from 20 Colombian cities that are available from the Colombian National Institute of Health (Instituto Nacional de Salud [INS] in Spanish) website (http://www.ins.gov.co/lineas-de-accion/Subdireccion-Vigilancia/sivigila/Paginas/vigilancia-rutinaria.aspx) from January 2012 to December 2015. These cities were selected because of continuous reports of dengue cases, altitudinal range (between 0 and 1457 m above sea level), population size (<1 million) and different ranges of temperature (Table 1).

Climatic Data. Daily climatic data were acquired from the Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM) of Colombia (www.ideam.gov.co), the Colombian public institution of technical and scientific support to the national environmental systems. Climatic data were acquired for the same time frame as the epidemiologic data. Data included variables related to temperature as follows: average temperature (TEMP-AVER), maximum absolute temperature (TEMP-MAXABS), minimum absolute temperature (TEMP-MINABS), average of maximum temperatures (TEMP-AVERMAX), average of minimum temperatures (TEMP-AVERMIN), maximum difference of daily temperatures (TEMP-MAXDIF), and averaged daily temperatures difference (TEMP-AVERDIF).

Statistical Analyses.

Relationship between Climatic Variables and Epidemiologic Patterns in Each City. To examine variability in epidemiologic and climatic data over different time intervals, we conducted analyses between incidence and the 7 climate variables at different lag times. Specifically, we conducted Spearman analyses at (1) 1-week intervals beginning with the current week of incidence and the previous 8 weeks